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Provided is a compilation of more than 75 articles which have been printed in "The Science Teacher" relative to teaching science in the junior high school. The two basic types of articles selected were (1) those that help science teachers think through their purposes, and (2) those that suggest appropriate methods and techniques for implementing their objectives. Part 1 relates points of view in discussing such topics as (1) teaching methods, (2) student evaluation, (3) grade placement concerning specific subjects and laboratory work, (4) trends and issues in junior high school science teaching, and (5) others. Part 2 provides articles on classroom instructional ideas. Included are (1) descriptions of units, (2) discussions on making equipment and materials, and (3) descriptions of activities, laboratory techniques, student activities, and science demonstrations. (DS)

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National Science Teachers Association

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1201 Sixteenth Street, N. W., Washington, D. C. 20036

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Foreword

The many commendable efforts that have been made to improve secondary school science courses and the competencies of science teachers have, to date, largely by-passed the junior high school. And yet the junior high school represents a truly critical level in the K-12 science sequence. For these reasons the NSTA Publications Committee has given high priority to the needs of junior high school science teachers in its planning of future publications. This volume represents the first of what we hope will be a series of publications specifically directed to the junior high school science teacher and other persons responsible for the development and administration of junior high school science programs.

In order to be an effective science teacher one must understand clearly why it is important for young people to study science and what the educational outcomes of such an effort should be. One does not come to this understanding merely by reading inspirational and informative articles; but it helps. Such reading helps to pinpoint pertinent questions about which we as science teachers should be thinking in our persistent efforts to clarify our personal thoughts regarding the aims and purposes of science teaching. It helps by presenting us with challenging ideas to stimulate and direct our thinking.

In order to be an effective science teacher one must also direct the learning activities of students in ways that will lead to their accomplishment of worthy objectives. This is the practical or "how-to-do-it" phase of science teaching. Evidence of interest in this phase of science teaching is attested to by the high attendance records at the how-to-do-it sessions at conferences and conventions for science teachers.

From the beginning the editorial advisory boards for *The Science Teacher* have subscribed to the policy that this NSTA journal should include both types of articles: those that help science teachers to think through their purposes and those that suggest appropriate how-to-do-its. An assay of past issues of *The Science Teacher* indicated convincingly that they contained many excellent articles, which if they could be brought together in one bound volume, would be helpful in meeting some of the needs of teachers. It was decided that the *TST* mine should be worked and our Executive Secretary, Robert H. Carleton, became both the miner and the processor. In this volume, Mr. Carleton has brought together what are considered to be "the best of *TST*". The Publications Committee takes this opportunity to express its appreciation for his fine work. We are all hopeful that there will be many readers of this volume and that all will find these materials to be helpful.

J. DARRELL BARNARD
Chairman, NSTA Publications Committee

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Quality Science for the Junior High School

HELEN E. HALE

Supervisor of Senior High School Science, Baltimore County Public Schools, Towson, Maryland

In many instances, the junior high school years provide the last opportunity science teachers have to work with *all* boys and girls. Regretfully, many students drop out at the end of the junior high school; others go into programs where they elect no more science. But, for the most part, in at least the seventh and eighth years of school, there is a captive audience for the science program. This situation presents a clear responsibility to establish high quality science teaching in the junior high school.

Growth and Developmental Characteristics of Junior High School Students

A prime requisite for building a quality science program for junior high school is an understanding of the students. Combining their thinking, a junior high school specialist and a psychologist have made the following analysis of the characteristics of junior high students.[1]

Physical Developmental Characteristics

1. A "resting period" in body growth is followed by a period of rapid growth in height and weight. Boys mature more slowly, sometimes lagging as much as two years behind the girls. The greatest rate of growth for girls occurs at about 12.5 years, then levels off to a plateau at age 15 or 16. The growth spurt for boys begins a little later, the peak being reached usually at 14.5 years, and leveling off at 17 to 20 years of age. In a typical seventh grade, approximately 75 per cent of the boys have characteristics of preadolescence, while most of the girls have already entered the adolescent stage of development.

2. Physical changes occur in rapid sequence. Initially the bones grow rapidly, while the muscles grow slowly. During this period the student frequently feels listless and awkward. He tires easily. The period of accelerated bone development is followed by rapid development of the muscles. Such imbalance in rates of growth results in poor muscular coordination, which may in turn result in clumsiness, poor posture, and even discomfort. Classroom procedures and activities should not be such as to accentuate the lack of muscular coordination of junior high school students in this stage of their development.

3. The junior high school student is keenly interested in all kinds of physical activity; he overflows with team spirit; he wants to engage in activities as a member of a group or team. Competition should be supervised carefully at this age.

4. Secondary sex characteristics are beginning to develop. In the seventh grade there are twice as many girls who have begun the puberal cycle as there are boys. Junior high school students seem to have little interest in practicing good health habits. At times they eat ravenously, while at other periods they are extremely finicky in their eating.

Social and Emotional Characteristics

1. As puberty approaches, a desire for increasing self-dependence is exhibited, and the child moves away from dependence on the family.

2. The junior high school student craves friendship. In early adolescence, there is a need for both acceptance by peers and the need to belong to a group.

3. The early adolescent exhibits a new interest in the opposite sex. He is no longer content with desirable relationships with his own sex. This is the most striking emotional change which takes place during early adolescence.

4. Children experiencing early adolescence often vacillate from one mood to another, are overcritical, uncooperative, and even rebellious.

Mental Development

1. The pattern of mental development established by any individual during his childhood may be disrupted during the upheavals of early adolescence. The most significant characteristic is that mental growth during these years reaches a plateau.

2. Ranges of maturity level are extreme among junior high school students.

3. A wide range of mental ages is evident among individuals entering junior high school.

4. Students at this period are able to make significant progress in understanding abstract symbols.

5. The analysis of causal effects in the area of

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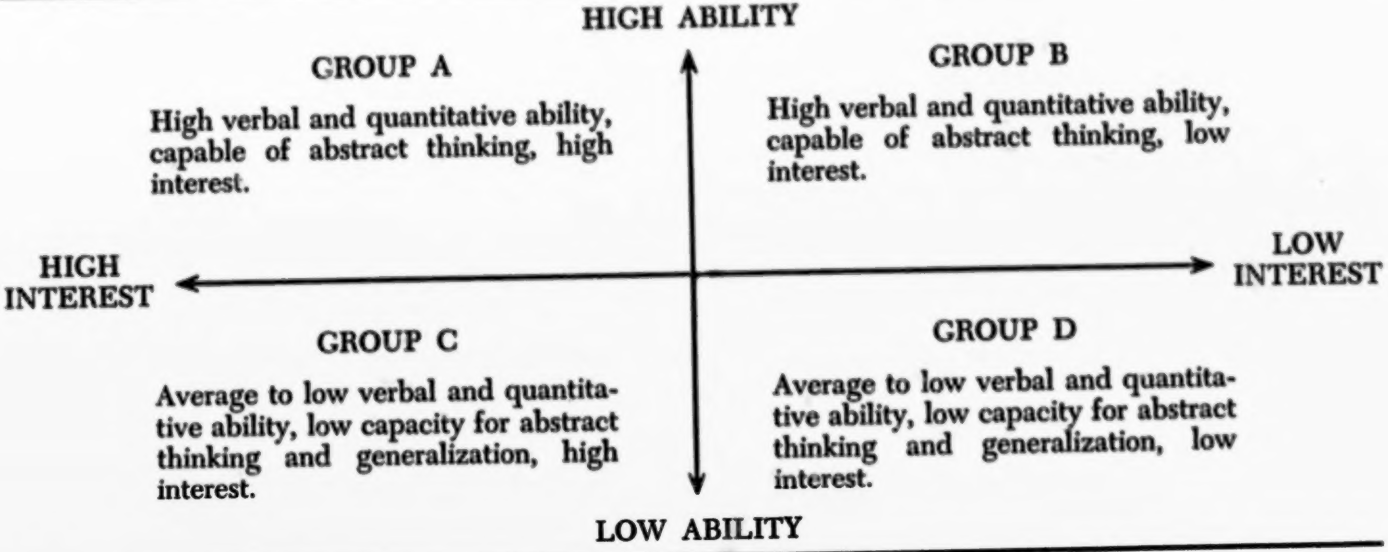
[1] Prepared by Dr. Fred Sloan and Dr. Myrne Nevison, both of Colorado State College, Greeley, Colorado.

science becomes increasingly based on operational factors of scientific principles.

The Range of Abilities

Junior high school students exhibit differing interests and marked differences in degree of motivation for school work. Several attempts have been made to categorize students in terms of both their abilities and interests. Paul Brandwein and his associates identify a number of groups, among them the science prone who are academically able, the average in science, and the science shy.[2] A group of junior high school science teachers envisions four groups: high ability-high interest, high ability-low interest, low ability-high interest, and low ability-low interest. The chart defining the four groups and the accompanying lists of characteristics are quoted in full.[3]



GROUP A

High verbal and quantitative ability, capable of abstract thinking, high interest.

GROUP B

High verbal and quantitative ability, capable of abstract thinking, low interest.

GROUP C

Average to low verbal and quantitative ability, low capacity for abstract thinking and generalization, high interest.

GROUP D

Average to low verbal and quantitative ability, low capacity for abstract thinking and generalization, low interest.

GROUP A

- High interest; quality rather than quantity.
- Creative ability—does more than required work.
- Works promptly with few errors.
- Active participation in class work.
- Dependability—well-disciplined.
- Welcomes corrections or suggestions.
- Understands assignments.
- Shows initiative; thinks, anticipates, plans.
- Shows reflection; works, thinks, creates on his own initiative.
- Responsible to self, family, and others.
- Preparedness.
- Formulates conclusions; knows of cause and effect.
- Reacts markedly and genuinely; courteous.
- Application of knowledge.
- Broadened outlook; cooperates; neat in work.
- High sense of conduct, ideals, morals.
- Organization is spontaneous.

GROUP B

- Some creativeness, capable of more.
- Understands assignments.
- Does little additional work.
- Participates in class discussion when called upon.
- Courteous and helpful.
- Little loss in false motions; every move counts.
- Works promptly and keeps busy.
- Work finished daily, seldom goes beyond assignment.
- Shows initiative—thinks of some new ideas on his own when challenged.
- Follows directions.

GROUP C

- Attentive during class period.
- Participates in class discussion at a concrete level of experience.
- Responds to suggestions and corrections.
- Does extra work based on experiences in class.
- Has some ability to retain facts.
- Follows leaders willingly.
- Completes his work daily; not adverse to new work.
- Considers knowledge a necessity.
- Can copy and compare.
- Reasoning is average—improvement is possible.

GROUP D

- Inattentive.
- Careless.
- Takes little part in class discussion.
- Unwilling or unable to attack new work.
- Does only the merest requirements .

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[2] Brandwein, Watson, and Blackwood, *Teaching High School Science: A Book of Methods* (New York: Harcourt, Brace and Co., 1958), pp. 58-70

[3] J. Ned Bryan, *Science in the Junior High School* (Washington, D. C.: National Science Teachers Association, 1959), p. 9.

- Forgets and misunderstands assignments.
- Repeats errors in spite of corrections.
- Responds unfavorably to suggestions.
- Easily discouraged.
- Spasmodic interest.

Confronted with few common characteristics and with a broad array of differences, one is struck with the difficulties in building an appropriate science program. A closer look, however, reveals that each of the common characteristics is clear-cut in its implications for both science content and teaching procedures, and that even the differences show a pattern.

Building a Quality Junior High School Science Program

Determining Objectives

Once it is clear what young adolescent boys and girls are really like, the first step in building a junior high school science program has already been taken. Information about the characteristics of students helps to establish the objectives for science teaching. A second activity basic to the formulation of objectives is to look at American and world society as it exists today—its ideals, its purposes, its problems, its direction—the climate of the times.

A third important prerequisite is an investigation of what is meant by the word "science." How is this word interpreted by scientists? By laymen? By educators? There has been considerable misunderstanding about the nature of the scientific enterprise. Some people have confused science and technology. Many have equated scientific thinking and problem solving. Actually, the scientific endeavor can be thought of as a composite of the many different activities carried out by scientists in their work. Basically, these activities are intellectual pursuits characterized by certain modes of thinking: discriminatory observation, categorization, quantification, hypothetical explanation, analysis and synthesis, correlational thinking, and construction of scientific models. The scientific enterprise involves the use of special tools and techniques which extend the human senses and other capabilities, but, essentially, it is a thinking activity for which the special tools are the means to an end. The products of science do bear on developments which are important in all aspects of living, but these technological developments are not science in themselves. The process aspect of the scientific enterprise is, therefore, the meaning of science which has major significance in determining scientific objectives.[4]

Some attention must also be paid to the findings of psychologists who are investigating what it is possible for early adolescents to accomplish: what concepts they can understand, and what values they will accept, what they are likely to appreciate, what skills they can learn. Admittedly, research results are meager in this area.

Because science objectives are broadly stated and usually turn out to be more or less alike for many different school systems, it could be argued that some central body should develop a list of objectives to hand out to various groups interested in developing science programs. But the process of thinking through one's purposes and establishing one's goals is a salutary experience for all administrators and teachers. Further, there are subtle differences in school systems, in situations, and in teaching personnel. These differences should be reflected in the objectives as they are finally recorded by any given group of teachers.

Selecting Science Content

At the risk of being overly practical and too obvious, one might say that the characteristics and needs listed on pages 1-2 suggest (1) that we should include some biology in the program, particularly the human physiology related to bodily and emotional changes in young adolescents; (2) that we must consciously introduce career information in the science curriculum; (3) that abstractions and generalizations should be included; (4) that we must develop the meanings of science as well as teach its principles; and (5) that attitudes, appreciations, and skills are a necessary part of the program.

Objectives give additional clues for content selection. They reiterate the need to embrace ideas, overarching concepts, and relationships as an essential part of the curriculum. They indicate the importance of studying about the variety of procedures employed by scientists. The nature of science itself is another essential element in the curriculum content—what is meant by a scientific introduction, the tentative nature of scientific conclusions, the interrelatedness of the scientific disciplines, the intellectual nature of the scientific enterprise, and the limitations of science as well as its possibilities.

Other factors also bear on the selection of junior high school science content. One of these is the greatly expanded elementary school science program. Another is the rapidly changing senior high school curriculum. The expansion of elementary school science means that much of the material of the traditional general science courses will no longer be included in the junior high school, and that more sophisticated concepts can replace the principles and other content now relegated to the early grades. Changes at the senior high school level mean that the quantitative aspects of science can be stressed more than formerly at the junior high school level.

Ideally, all levels of education would work together under competent leadership to establish in systematic fashion a twelve- to fourteen-year sequence for elementary and secondary school science. In some places this is now going on. A less satisfactory but, in some instances, the only realistic *modus operandi* at this time, is for those concerned with elementary, junior high, and senior high school science to confer with each other from time to time, learn what each other is doing, make needed adjustments in their respective curricula, and thereby achieve a fairly well articulated science program.

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[4] The foregoing description of the nature of the scientific enterprise was adapted from discussions held at the Conference on Selected Problems in Secondary School Science, sponsored by the National Science Foundation and conducted by the National Science Teachers Association, Washington, D. C., November 1959. A report of this conference, titled *Planning for Excellence in High School Science,* is available from NSTA; price $1.00.

Organizing the Science Program

The organization of content must go hand in hand with the selection process. And, again, flexibility must be considered. There are numerous patterns and sequences for the organization of junior high school science at the course level. The elements present in these various arrangements include general science, health science, earth science, physical science, and biology. The chart below shows some of the typical patterns.

Grade Seven	*Grade Eight*	*Grade Nine*
General Science	General Science	General Science
General Science	General Science	Biology
General Science	General Science	Earth Science
Health Science	General Science	General Science
Earth-Space Science	Biological Science	Physical Science

A decade ago there was some experimentation with science as part of the core program in grades seven and eight, but most school systems which tried this are now teaching science separately. A few localities developed fused mathematics-science courses for the first two years of the junior high school. Most of these systems are going back to separate courses. These developments are not surprising in a time when increased emphasis is being given to the upgrading of subject matter competence of all science teachers. It is difficult for a teacher-in-training to major in more than one subject or to find some other way to become well-informed in two or more subject matter areas.

Another factor which bears heavily on the selection of junior high school content is the rapid proliferation of scientific knowledge. The enormous increase in scientific information makes coverage of all knowledge utterly impossible and the problem of content selection can become acute. Various solutions are being tried: the block-and-gap approach,[5] science-as-method rather than science-as-content, and programs which emphasize basic principles and eliminate most of the applications, social implications, and the like. No one of the various programs seems to be the ideal solution for all junior high schools. Further experimentation with the above-mentioned plans and new approaches are needed.

Effective Teaching Procedures

The foregoing sections of this report have provided a point of view about junior high school pupils and total science programs. It is hoped that the following discussion will give some specific leads for helping science teachers improve the quality of their day-to-day teaching.

1. *What kinds of laboratory exercises should the junior high school science program include?*[6]

Disregarding for the time being those factors which are peculiar to the junior high school phase of the total science program, let us review briefly general criteria for evaluating laboratory exercises. Laboratory exercises contribute to the learning of science by boys and girls to the extent they "(a) add reality to the text material, (b) develop first-hand familiarity with the tools, materials, or techniques of the profession, (c) allow the student to demonstrate for himself something that he already knows to be true, (d) give the student an opportunity to pit his laboratory skills 'against par' in seeking an experimental answer, or (e) create opportunities wherein the student predicts events or circumstances and then designs experiments to test the accuracy of his predictions."[7]

Among these criteria, the last one seems to hold maximum significance. In effect, this encourages teachers to use the laboratory as an environment in which boys and girls can take their own little excursions into science. From this point of view, those laboratory exercises become most valuable which allow the teacher to bring before his students a maximum number of the events and circumstances of the natural world. They gain increased value if the student is encouraged to identify the subtle clues whereby relationships between these events and circumstances and things already familiar to the students can be established. Under ideal circumstances, students will have opportunities to frame new hypotheses regarding possible relationships between naturally occurring events and circumstances and then to design experiments whereby these hypotheses can be tested. Continuing at this ideal level, students will be able to conduct such experiments, evaluate their conclusions, and see clearly the next steps which await tomorrow's scientists.

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[5] See I. Bernard Cohen and Fletcher G. Watson, *General Education in Science* (Cambridge: Harvard University Press, 1952) and Paul Preger, "Should General Science Be So General?" *School Science and Mathematics*, LVIII (December 1958), 710-12.

[6] Sub-sections 1, 2, 3, and part of 5 were contributed by John H. Woodburn, Chemistry Teacher, Walter Johnson High School, Bethesda, Md.; sub-section 8 by Eugene Peckman, Science Supervisor, Pittsburgh; and sub-section 9 and 10 by Abraham S. Fischler, Assistant Professor, Harvard Graduate School of Education.

[7] Donald H. Andrews, *Educating a Chemist.* (A report on the conference held at The Johns Hopkins University, October 16-20, 1957, sponsored by the National Science Foundation), pp. 52-53.

Much is being done by creative, imaginative teachers who are anxious to provide appropriate laboratory exercises for junior high-school-age boys and girls. Much remains to be done. Herein lies a resource adequate to test the mettle of any person whose responsibilities lie in the junior high school phase of science education.

All of the foregoing does not mean that student and teacher demonstrations have no part in junior high school science. Obviously, they do. But most teachers and administrators already realize their importance and have considerable know-how for effective use of demonstrations. And, unlike the situation for individual laboratory work in general science, the literature is filled with suggestions on demonstration teaching.[8]

2. *What part can student projects play in the improved junior high school science program?*

For our purposes here, we consider a student science project as something over and beyond the things ordinarily required or set up for all of the students in any group. A project is the study of something—what it is, how it happened, is happening, or might be made to happen. Ideally, a student project begins when a boy or girl becomes curious about something and arranges things and circumstances in such a way that he can formulate hypotheses, gather data, and complete an experimental investigation of the thing which arouses his curiosity. Individual, self-directed projects become a wonderful opportunity for each pupil to pursue his curiosity as actively, rapidly, and to as sophisticated a level as his ability permits.

In current practice, student projects at the junior high school level seem to be influenced more by points of view carried over from the elementary school than from the senior high school level. In all too many cases, the student's time is invested in elaborate collection, construction, poster, notebook, or model-building projects. In very, very few cases do these projects lead the youngsters on a genuine excursion into science. It would seem that other activities of higher intellectual nature would be a more worthy investment of the enthusiasm and devotion which junior-high-school-age youngsters can bring to their science courses.

3. *Does the case history approach have something to offer science education at the junior high school level?*

The case history approach to the teaching of science attempts to place the student in a situation where, so to speak, he looks over the shoulder of a scientist at work. To the extent that junior-high-school-age boys and girls are peculiarly susceptible to learning through vicarious approaches, the case history method holds significance for those who plan science education activities. The author believes the junior-high-school-age boys and girls are particularly susceptible to this type of learning and, consequently, looks with favor on the case history method.

The case history method is inextricably linked with James B. Conant, having been explored in great detail by him during his years as professor and president at Harvard University. The writings of Dr. Conant and of his students are readily available and should be consulted carefully by those who would understand this contribution to the advancement of science education.

4. *What audio-visual activities are appropriate in junior high school science?*

It seems unnecessary in this publication to discuss the ways in which audio-visual aids may be employed in junior high school science. Any of the standard references on audio-visual education or a good science methods book will give the needed information. We cannot refrain, however, from emphasizing the chalkboard as the science teacher's most useful visual aid or from pointing up the value of the bulletin board for teaching current developments in science. The display case is also a useful adjunct in science teaching.

5. *How can community and field study contribute to the junior high school science program?*

The more conventional field trip taken by groups of students should also be encouraged with particular emphasis on the value of the school building, the school campus, and the immediate community. In the school building itself the heating system, the stage fittings, the audio-visual room, and the shops may be sufficiently pregnant with applications of science to justify an organized observation by the class. There are living things, rocks and soils, streams, and other resources on the school grounds. The community offers zoos, parks, industrial plants, university and governmental laboratories, installations of utility and communications companies, the airport, and the science agencies for health, water supply, and sewage disposal.

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[8] Charles H. Boeck, "Laboratory Approach to Science Education," *Education*, LXXX (September 1959), 21-3; Zachariah Subarsky, "Toward More Efficient Laboratory Work in Science," *The Science Teacher*, XXII (May 1956), 265-6; Curtis E. Johnson, "Expansions in Laboratory Opportunities for Students in Science," THE BULLETIN of the National Association of Secondary-School Principals, XLI (April 1957), 258-9; Edward F. Potthoff, "Use of Demonstrations in Science Teaching," *Science Education*, XXIX (December 1945), 253-5; and Harry A. Cunningham, "Lecture Demonstration *versus* Individual Laboratory Method in Science Teaching," *Science Education*, XXX (March 1946), 70-92.

6. *How can a junior high school science teacher use language arts activities?*

Along with observation of real materials, laboratory experimentation, and project work, students depend upon reading and other language activities for much of their learning. As a matter of fact, even the "doing" activities of science are sometimes of little value if they are not coupled with reading, writing, listening, and discussion.

7. *What evaluation techniques can junior high school science teachers use?*

There is a serious lack of standard tests for junior high school science.[9] This is not surprising when one notes the variety of general science courses. Even though there is an ever-increasing array of subject matter from which teachers can select, it would seem that the test constructers could devise some instruments to measure the objectives for general science on which there is a common emphasis—the skills, attitudes, appreciations, and understandings (quality of concepts), which appear in most courses of study and curriculum bulletins.

At the local level, junior high school teachers should be encouraged to experiment with construction of test items clearly related to the objectives for general science and to gain skill in using check lists for student traits, laboratory-type tests, self-evaluation instruments for students, and other techniques which will get at the major goals of science teaching better than conventional tests now do. There should also be increased emphasis on essay-type examinations at the junior high-school level, particularly with gifted and superior students.

8. *What facilities are needed for junior high school science?*

The objectives of science teaching and the facilities to achieve them are as inseparable as the forces of action and reaction.

There should be an array of facilities for the full range of student activities so that boys and girls can gain a direct and intimate experience with the real materials of science. There should be an array of facilities for the full range of teacher activity. The direction should be toward reducing to a minimum the time the instructor will give to being stock boy, technician, or janitor and to raising to a maximum the time students will have full responsibility for setting up, using, and returning to storage the equipment they use.

Referring to commonly existing patterns of science facilities in terms of their contribution to valid science-teaching goals, one finds that national practice and standards are woefully inadequate. A very common practice is to install a large demonstration table at one end of the room with chalkboard behind it and then add one or two storage cases in the corners. When classes tend to be large, armchairs occupy the student area. Rows of tables facing the instructor's desk take up more space, are inflexible, and restrict student movement, especially when additional armchairs, to take care of the large home room, have to be put in the aisles. Electricity, gas, and water services are commonly restricted to the demonstration table. There may be a stock room off the end of the room.

In contrast to the above picture, let us set forth some ideals with regard to facilities and see how close we can come to their realization in an actual design for a junior high school science classroom-laboratory. We shall include facilities and their storage for both teacher demonstration and student laboratory use.

Standards for Facilities for Teacher Demonstration

1. Facilities stored in complete set-ups, or arrays, ready to use but possible of assembly, if desired, as part of the demonstration.
2. Facilities stored at the point of use, even in the actual position for use.
3. Facilities, storage, and use planned in relation to services required.
4. Storage which makes facilities available instantly over long periods of time for various purposes: orientation to a new topic, development of concepts, unit summary, and final testing.

Standards for Facilities for Student Laboratory Use

1. Storage for students of multipurpose items to reduce costs and storage problems and to give students experiences in assembly.
2. Storage at the point of use; i.e., at each student station, pair of stations, or four-student table.
3. Services in relation to student stations to maximum practical degree: electricity to each pair, gas to each table, water to pairs or larger groups of tables.
4. Supplementary and varied enrichment project areas for special assignment, with neded storage and services.

Every opportunity should be provided to enable the teacher to get away from obsolete and stereotyped facilities. New furniture arrangements open new possibilities for student activity and demonstration. There must be flexibility for teacher growth and creative expression. Worktop space, facilities, and apparatus must be provided to give at least the same proportion of class and laboratory activity which now exists in the best senior high school situations for chemistry, physics, and biology. Tools, space, and raw materials must be provided to enable teachers and students to devise, improvise, and adapt demonstration and student equipment from every phase of life activity. They should not be restricted by the narrow limits of science apparatus catalogs. Creative teaching requires creative facilities!

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[9] *Analyses of Science Tests.* Washington, D. C.: National Science Teachers Association. 1959.

9. *How can we develop guide lines for the academically able?*

To write a formula which could be used nationally for the education of our able youngsters would be impossible and presumptuous. Each local community must establish its own method for identifying these students as well as for educating them. Whether they are educated in separate groups or in well-mixed classrooms is probably of minor consequence; what does matter is the type and quality of experiences to which they are subjected while learning.

The very nature of the academically able student provides some guide lines which apply to his education. He learns rapidly, has varied interests, and is adventuresome. What then are the guiding principles to keep in mind when working with the able students in junior high school science?

Students should be encouraged to study an area in depth. Rather than cover many areas at one grade level, the course should be organized around "big ideas." The academically able student should be encouraged to read extensively, to hypothesize, to experiment on a problem in which he is truly interested, to work in small groups, and to communicate both verbally and in writing. He should be motivated to pursue questions in areas where the frontier scientists still have not found the answer. Too often, students of junior high school age feel that science has found all the answers, and that there is little more to be learned. Teachers should be encouraged to say "I don't know" or "We don't know," and urge the student to search the literature for further information and to speculate. Keep the discussion "open-minded."

The academically able student needs to be encouraged to work with science materials to acquire competency in laboratory techniques and methods. This should help to develop a feeling for the work of scientists. If the problem investigated is one in which he is interested, reaching a successful conclusion will enable him to gain the satisfaction gotten from the discovery of "something new." The student should be encouraged to work independently while under the guidance of the teacher.

The introduction of the quantitative approach to science should be encouraged as the able youngster can deal readily with mathematical calculations. The concept and practice of dimensional analysis can be incorporated in the junior high school science program.

Resource personnel should be made available to able students. Those members of the community who are engaged in science and its proceedings, whether research or applied, should be encouraged to meet with these students to guide them and possibly to "teach" them. Special clubs may be organized where students can be encouraged to work on their laboratory projects, or where guest speakers may be invited. Club sessions may be scheduled during the school day or in the evenings and on Saturday. The services and materials available from the National Science Teachers Association for use with Future Scientists of America (FSA) Clubs are especially helpful and suggestive of procedures and activities desired and approved by science teachers and other educators.[10]

10. *What guide lines are valid for the slow learner and the science shy?*

A distinction must be made between the slow learner and the science-shy student before discussing guide lines for working with these students in the junior high school. The slow learner usually has an IQ between 75 and 90. Within this group there seems to be a large proportion of students with defective sight and hearing, as well as malnutrition. Since their basic intelligence is not high, they have difficulty in dealing with abstractions. Furthermore, their attention span is of short duration and their academic interests are low.

The science-shy student, as referred to in this publication, is of average or above average intelligence, but he is oriented toward the humanities, arts, or social studies, rather than science and mathematics. This student is capable of working for longer periods of time than the slow learner and, when motivated, he thinks with abstractions.

What are some of the guide lines and practices which can be used successfully in working with these two kinds of students?[11]

As the normal class period is too long a time for the slow learner to engage in one type of activity, some teachers divide it into three or four sub-periods. These might consist of an activity time, discussion time, summary, and preparation time. The activities carried on may serve to motivate the students or to develop certain skills. These activities must be concrete, easily understood, and related to everyday life. Directions for carrying out the activity should be simple and explicit. Students can work individually or in groups, since both practices have their value.

This technique may take time to develop, but it enables the students to develop self-discipline, respect for the other fellow, and good listening habits. The final portion of the lesson is used to summarize the main ideas; these are usually written on the board so that the students can copy them. During this time, the teacher may walk around and make personal contact with the individual pupils. Preparation for the next day's assignment is given so that students may read in school with a purpose. Short reports or committee reports might be given, but the length of time devoted to this activity should be restricted to a maximum of about ten minutes. As these students need help in working together, the activities and assignments suggested by the teacher can give them practice in cooperation, and can develop group and personal esteem.

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[10] For information about FSA, write to the National Science Teachers Association, 1201 Sixteenth St., N.W., Washington 6, D. C.

[11] A number of practices found successful in dealing with the slow learner can be found in *Teaching High School Science—A Book of Methods* by Paul Brandwein, Fletcher Watson, and Paul Blackwood. Many ideas in this article stem from this book.

The techniques mentioned in the preceding paragraph are applicable to the average and above-average students as well. Therefore, in heterogeneous groups, the teacher might begin the semester with this technique and then vary it for different individuals in the group. This technique can be modified by individualizing assignments.

The science-shy student who is oriented, say, toward social studies, may be motivated in science by starting with a social problem. For example, "Why is strontium 90 considered dangerous to the human being?" A discussion of this type of question will force the student to read about the problem of fallout. In order for a student to understand this problem, he will need to know about radioactivity: what it is, how it can be detected, and what benefit, if any, it is to the human race. By starting with a social problem, letting students read, work in groups and hold discussions, the science-shy student may become interested in science and see that an understanding of scientific principles is important for all citizens. Surely he will develop an appreciation for science by understanding that the scientific enterprise has had a tremendous impact on our society.

Since we are living in an age when science is playing a more important role every day, we have a particular responsibility to these boys and girls. They need to understand the place of science in our society. Teachers must work more adroitly to make these students understand what science has meant to our society, and how, through science and the application of the various methods employed by scientists, we can make our world a better one.

Check Your School Against These Twelve Trends

In summary, what is the direction in which junior high school science is moving? Perhaps an even dozen trends are worthy of mention. To be sure the twelve overlap and interrelate, but, set down separately, they become a check list for surveying school science programs.

1. *The program is planned but flexible.* The first trend has to do with curriculum provisions. In the broad sense, the junior high school science curriculum is more prescriptive than it was a decade ago. With respect to specific content at the classroom level, however, there is considerable flexibility and the teacher is free to adapt the prescribed program to the particular pupils he is teaching.

2. *Science is thinking.* The general science program has gained in intellectual stature. Attention is now being directed to the conceptual aspects of science and to the thought processes of both historical and contemporary scientists. Gadgetry and technology are receiving less attention as objectives of instruction and are being made to serve rather than be served by reason and mental constructs.

3. *Science is philosophical.* The attitudes related to science are gaining importance in the junior high school program. Young adolescents are thinking about the nature of the scientific enterprise. They are pondering the place of science in contemporary society and are considering both its possibilities and its limitations.

4. *Science is quantitative.* As more science and mathematics are being included in the elementary school program, it has become possible to include, for many students, the quantitative aspects of science at the junior high school level. Students learn that scientific inductions are based on data, that data are made up of quantities which have both numerical value and dimension, and that principles and laws of science can often be expressed mathematically. They learn to handle scientific notions in a quantitative manner.

5. *Programs are articulated.* There is a trend toward improved articulation of the junior high school science with other junior high school subjects and with both the elementary school and the senior high school science programs. Teachers and administrators working at different levels and in different subject matter fields are learning to plan cooperatively. More and more school systems are seeing the wisdom of appointing personnel with responsibility for the total K-12 science program. The number of science coordinators, directors, and supervisors is increasing.

6. *Science is doing.* A sixth trend points up the "doing" activities of science. Junior high school science projects are becoming commonplace. Field work is written into many programs. There is a growing emphasis on individual laboratory work at the junior high school level.

7. *Facilities are improving.* Better teaching materials and facilities are imperative when both the intellectual and the experimental activities of science are increased. Textbooks are getting better. More references are being supplied for the science classroom and the school library. Audio-visual materials are becoming more abundant. Growing budgets for equipment and supplies reflect the trend to provide a wide variety of materials for experimental and developmental activities of all kinds. General science teachers have come to expect a well-equipped classroom laboratory with adequate provisions for storage and for the varied activities of a modern science program.

8. *Science schedules are changing.* There is a trend to provide more time for science in the junior high school. In many places, science is required of all students for all three years of the junior high

school. In some schools double laboratory periods are being scheduled.

9. *Grouping is becoming homogeneous.* Although not unique for science, the trend toward tighter grouping is evident in most junior high schools. The so-called homogeneous grouping process facilitates adaptations of the curriculum for various groups. Special provisions and courses are being developed for the academically talented. In some cases, biology is scheduled in grade nine for these students. In other instances, new and unique courses have been developed. Special attention for the slow learner in science is also evident.

10. *Extra-classroom science is popular.* There is a growing trend to extend science activities beyond course requirements. Junior high school science clubs are increasing in number. Seminar groups, often meeting outside the school day or week, are growing in popularity. Science camps and special summer programs are gaining favor.

11. *Public interest is high.* Keen interest in the science activities of the school is now typical of parents and other citizens. Organized groups are also showing their concern as they provide many materials and services for both teachers and pupils. Auxiliary agencies affecting the junior high science program include various branches of the Federal government, industrial and business groups, professional societies, private foundations, and, to some extent, colleges and universities. One direct result of the activities of public and private agencies has been an increased emphasis on science careers and the inclusion of specific career information in many junior high school science courses.

12. *A great deal is expected of science teachers.* A natural consequence of public interest in science and of some of the other trends as well is that more and more is being expected of the junior high school science teacher. Through subsidized summer institutes and academic year programs, the National Science Foundation is making it possible for teachers to gain additional training. While many citizens are according recognition to the science teacher, they are also looking to him to do a superlative job. A general science teacher is expected to have firm control of a large body of basic subject matter, to understand the historical and philosophical aspects of science, to keep informed about recent developments, to work with both elementary school and high school teachers in effecting articulation, to handle laboratory and field activities efficiently, to learn to use a great many new learning aids, to adapt a program to the needs of a whole range of pupils, to cooperate with outside agencies interested in furthering good science teaching, to give untold hours of extra-classroom science activities, and to participate in in-service programs. He must find time to plan and teach lessons, keep his equipment in working order, read journals, take courses, attend lectures and meetings, and work with individual pupils on their projects. It is a demanding but exciting time to be teaching junior high school science.

SECTION 1
Points of View

Trends and Issues in Junior High School Science

DONALD W. STOTLER

Supervisor of Science, Portland Public Schools, Portland, Oregon

(SEPTEMBER 1956)

A DISCUSSION OF TRENDS and issues in science at the junior high school level must face three questions: What needs to be done? What is being done? What could be done?

WHAT NEEDS TO BE DONE?

Somehow the science demands of the future must be met. The junior high school can and must carry a proportionate share of the responsibility. It is doubtful if it has done so in the past or is doing so now. Science teachers must produce the numbers, kinds, and quality of scientists which the future will demand. At the junior high school level, similar types of experiences are apparently needed by both future scientists and non-scientists. Four needs are outstanding.

1. Increased Initiative. A study was conducted during World War II as to which soldiers were most adaptable and showed the most initiative. One factor emerged most consistently. The farm boy tended to show the most initiative and to be the most adaptable. Does this mean that farm life comes nearest to being what we call the experience curriculum? The farmer must "learn by doing" as each problem arises. In fact, a farmer would probably become bankrupt if his day were reorganized by experts into set periods devoted to learning in a specific area; that is, to mathematical calculations during one period, written communication another, scientific applications another, ad infinitum. It is doubtful if even his subject matter knowledge would increase; almost certainly his initiative would decrease.

Prior to 1900 the school was compartmentalized and dictatorial. Most people attended for only a few years. The school was more than offset by the experience curriculum at home in daily frontier and farm life. Since 1900 we have retained more and more students for longer periods of time in the schools while they have decreasingly had the experience curriculum offered by rural life. If we are going to continue our American initiative we must replace compartmentalized and teacher-dominated classrooms. We must move the frontier and the farm into the classroom and give students a 12-year sequence based on an experience curriculum, where the student is the initiator and the teacher a stimulant and a guide. Students at the junior high school level must be permitted to initiate many of their own educational experiences if initiative is important.

2. Increased Interest. Almost the entire curriculum of the kindergarten is based on the interests and questions of the students. As students progress through the school, however, studies show that the students ask fewer questions and the teachers more, until in high school by far the greater share of questions are asked by the teacher. This is not done by the teacher to deliberately ignore the interests of students, but rather to keep the students within the definite compartment or subject area which the teacher was employed to teach. For the problems of students do not respect the logical boundaries set out by the experts.

It is interesting to note that the small child is very similar to the scientist in two most important respects. Both have uninhibited curiosities and both are uninhibited in their ability to initiate. The scientist might almost be considered a person who has run the gantlet of the typical curriculum and managed to retain his childish curiosity and initiative. The junior high school level is a crucial stage in deciding how many will run the gantlet successfully. If interest in science is to be retained, the student's present interests must be an important part of the curriculum fabric and the teacher's part must be woven so as constantly to increase the student's span of interest.

3. Increased Scientific Thinking. Even the methods used by scientists are not completely different from the thinking of the child, for "scientific method" is but the efficient use of ordinary thought processes. Studies show that a small child approaches problems in the same manner as adults.

The difference is one of *degree* of knowledge and skill in thinking rather than a difference in *kind* of thinking. Just as the problem-solving of the child, the layman, and the scientist use the same approach, but differ in skill, so is there a close relationship between scientific thinking and democratic process. Both seek to clarify the true nature of a problem when it arises; both involve gathering and evaluating data about the problem; both involve seeking out the possible answers; both involve experimentation and the comparison of the results with what is already known. In democracy the process involves large groups, whereas in science the process may be an individual affair. However, even in science there is a trend toward cooperative problem solving in the laboratory as illustrated by science teams developed in some industrial research laboratories. The West Coast conferences conducted by NSTA in 1954 and 1955 are unique, research-team efforts of science teachers.

4. Increased Interrelationship of Content. When science embarks upon a problem such as how a car or a cat operates, it proceeds by dissection—by dividing or compartmentalizing the subject. This narrows the context of each experiment, permitting more people to operate on the problem without duplication. It also tends to increase the accuracy of each experiment. Slowly the time comes, however, when the carefully dissected and individually studied parts of the subject, whether a cat or a car, must be put back together and considered as they influence each other in the function as a whole. This requires the fusion of knowledge into larger and larger contexts.

When science first arose on this earth it set out to understand the whole universe. As with a cat or a car, scientists began by dissecting the universe into logical subjects or compartments—geology, geography, chemistry, and others. During this pre-atomic era it was natural that the schools should also be compartmentalized into the same areas. With the advent of the atomic era, science came of age. Inevitably the need arose to begin to put the universe back together. The universe as a whole became more closely related by the theory of relativity and other ideas. The compartments began slowly to fuse into larger and larger contexts. Naturally, fused subject matter also began to be demanded of the school. It is increasingly difficult to justify separate studies of isolated science topics such as heat, light, and sound, or even to justify science as a separate course at the elementary and junior high school levels.

All four of the above mentioned needs are harmonized in the problem-solving approach as needed for an experience curriculum. The problem-solving approach uses *scientific* and *democratic methods;* demands *fused subject matter;* begins with the *child's curiosity;* and requires time blocks long enough to permit the *child to be the initiator.*

WHAT IS BEING DONE?

Although the junior high school apparently came into existence primarily out of economic considerations, plus concern about retaining children in school longer, the justification most widely proclaimed for this new school was its new possibilities for educating students. Theoretically this school could provide more self-government, more interest groups or clubs, more personalized treatment, better vocational orientation, and besides a well-rounded homeroom or "core" experience, a variety of brief exploratory experiences in areas that could be expanded in senior high school.

One of the most enthusiastic followers of the junior high school movement was a supervisor from the Portland Public Schools—this school system has as yet no junior high school. Two years ago this supervisor accepted a position with Columbia University's Citizenship Education Project. It entailed much visitation of West Coast schools. He said that the greatest educational disappointment of his career was the typical junior high schools he visited. They were small high schools with little or no homeroom experiences offered, in the great desire to offer more and more separate content subjects taught by specialists. Science was taught as a separate subject at all three grade levels. Not content to have special subjects, there was a decided predisposition to separate these subjects into homogeneous grouping on a basis of IQ scores. This pattern apparently is typical over the nation. Furthermore, this trend in the junior high school is being imitated generally by the last two grades in the eight-year elementary schools, which is another development to study.

WHAT COULD BE DONE?

The issue we face is not one of praising or rejecting the junior high school as an educational institution in comparison with the eight-year elementary and four-year high school sequence. Either type of school can do very little educationally that cannot be done as well in the other—whether the trend is toward science in the homeroom or toward separate science.

The issue is whether science shall be integrated into homeroom experiences, or taught as a separate subject, or both. From the point of view of educational philosophy, the issue is not as divergent as it appears on the surface. Most junior high school teachers and administrators would agree that ideally science at this level should be in the homeroom if the homeroom teacher would do, or could be led to do, a good job of science teaching. They plead that it calls for a science expert, and homeroom teachers are not interested in being brought to this level or haven't the time and energy to do so in terms of the pressures brought upon them to be experts in other areas also. They point out that students at this level need to contact many people, constant contact with but one teacher does not meet the needs. Also, the so-called gifted science student is apt to "wither-on-the-vine."

Actually, then, the basic issue at the junior high level is, *Can science be taught adequately in the homeroom?* Before giving a negative answer to this question let us consider several ideas and techniques for gaining a sound science program based upon homeroom experiences. (In school systems where the ninth grade is part of the high school, the ninth-grade science might well be retained separately until a successful seventh- and eighth-grade science is established.)

HOW TO DO IT

A. It is unlikely that junior high school science will get much duller if all separate science classes are eliminated—in fact, this cancels one of the main excuses for not teaching science in the homeroom.

B. Administrators and supervisors can do much by dealing with teachers as they would like to have teachers deal with their students. If teachers are to reassure students and make them feel secure enough to be led into experimentation and increased learning, it must be equally applicable to teachers. For example, if the teacher insists she doesn't teach science in the homeroom, it can be pointed out that she actually does, although it may not be labelled science. This approach will tend to put the teacher in a frame of mind to feel more secure with where she is educationally and hence more willing to become experimental with science in the classroom.

C. Rather than indicating that science is an additional subject in the homeroom, teachers can be encouraged to promote a "let's find out" attitude in all homeroom activities. In this way they can begin by merely extracting more out of whatever the homeroom happens to be doing. All things are based upon such science phenomena as gases, liquids, solids, radiation, vibrations, etc. For example, painting a mural involves color (What causes it and how is it brought about?) and paints involve liquids and solids (What causes these states and how are they related to gases?); music involves sound (Can we find a basic science principle that would explain how low and high notes are created by all instruments—including the voice box in our throats?).

D. One of the greatest aids to the homeroom science program, in my experience, is to discard all basic science texts and develop a pool of science books at all reading levels and on all subjects. A limit can be set (in terms of available money) on the number that any teacher can have at a given time (although rotation of books should be encouraged)—but no limit should be set on the kinds of books or reading levels the teacher chooses. The books will then come to be used as reading books as well as for science content. They are also especially useful for both the gifted and the retarded students. In addition, teachers become interested in reading these varied books and this offers background in science for them.

E. In some cases, teachers capable of doing an excellent job of homeroom teaching can be given released time to help improve the homerooms of other teachers.

F. A centrally located workshop area may be set up, usually as a part of an instructional materials center, where teachers may exhibit samples of their homeroom work as a suggestion for other teachers. Such an area should contain tools to enable teachers to experiment with classroom ideas under supervision.

G. In-service classes should be set up where teachers are taught with the same methods which administrators would like to see teachers use in the homeroom.

IT CAN BE DONE

H. Resource units suggesting a problem-solving approach and many science activities related to the total curriculum should be made available for new teachers or teachers who are just embarking on the unit teaching method. However, teachers should not consider these units as final in form or as required teaching. Teachers should be encouraged to build their own units with their own students, but with one eye to the general sequence laid down by the school board.

I. Science kits are rather easily prepared by selecting several books from the science booklist on a particular subject, such as weather, and at a general grade level. The books can then be examined to see what materials are needed for the experiences. The books and materials are then placed in a box. These kits can be made available like films on a loan basis; also as with films, the grade level at which each is used should be largely up to teacher judgment.

J. Each year there should be definite curriculum projects laid out as new steps toward an experience curriculum. Many devices can be suggested—science fairs, tree-planting projects, community resource surveys, etc. The use of resource people in the homeroom and trips into the community help offset the charge that students see only the teacher in this type of educational design.

In my observations of both government and education, one general principle stands out—the obvious is seldom true. Democracy is the least obvious form of government and the experience curriculum is the least obvious form of education. I'm proud that our country's fathers plunged into the least obvious form of government, while others clung to more obvious governmental structures. I believe our children will be prouder of us if we move resolutely towards the form of education we generally agree would be preferable.

Science Interests of Junior High School Students

HAROLD S. ANDERSON

Chairman, Education and Psychology Division, Southern State Teachers College, Springfield, South Dakota

(OCTOBER 1954)

Junior High School Science Teachers Should Know the Interests of Their Students.

RECENTLY, a seventh grade science class visited a hospital. During the entire tour, the members of the class listened raptly to the hospital director's explanations of the equipment and facilities of the hospital. They were interested. Teachers and parents who know them realize that such an interest is typical of this age group.

Unlike adults, seventh graders are interested in everything that goes on about them. Their questions are typically: "What makes it work?" "Why does it look like that?" "How does it happen?"

Wise science teachers are taking advantage of this natural inquisitiveness. They are gaining awareness of the importance of children's interests for effective learning. Since it is known that children will work harder, and learn more about science topics that are interesting to them, why not use their interests to guide the selection of science subject matter and activities?

Science in the community is one topic of interest to seventh grade students. Television is another one. This year the seventh grade science class studied television. They didn't learn how to construct or repair a set, but they gained a basic understanding of the principles involved. They learned how the image was televised and broadcast, the function of the antennae, and how the image is reproduced on the screen.

It would be difficult to list all of the scientific principles which were encountered by the students in their problem solving activities about television. They studied such topics as radio waves, electricity, electrons, vacuum tubes, light, and atoms.

How Can Interests in Activities and Subject Matter In Science Be Determined?

It is as important to know what students are interested in *doing* in science as it is to know their interest in subject matter. For years teachers and administrators have used various devices to determine the interests of students. One of the common methods used has been some form of questionnaire. Too often these questionnaires have included only direct questions about different topics or fields of subject matter. It is questionable whether the results indicate the students' natural interests, and they have not determined the activities of science in which students are interested.

Since students' associations with science are made through a variety of activities, it would seem desirable that a questionnaire determine not only in what students are interested but also what activities they are interested in doing. Can indications of both interests be determined in one instrument?

With this question in mind, Dr. Donald G. Decker, Chairman of the Division of Sciences, Colorado State College of Education, worked with preservice teachers in the fall quarter, 1953, to originate a new kind of science-interest questionnaire.

The questionnaire consisted of two main parts, activities and subject matter. Eighteen different activities are included in the questionnaire, such as: owning, using, seeing, hearing, taking apart, discovering, and giving reports. The items include these five major areas of science: 1. *Living Things,* 2. *The Human Body,* 3. *The Earth,* 4. *The Universe,* and 5. *Matter-Energy.*

The questions are grouped for convenience in tabulating. Questions pertaining to living things are numbered 1 and questions pertaining to the human body are numbered 2.

Parts of the questionnaire are shown below:

2. What have you used?

  1. Have you used a chemical to make a plant grow better?
  2. Have you used a microscope to examine cells from a human body?
  3. Have you used a compass to find directions?
  4. Have you used a star map to locate stars?
  5. Have you used a nail and some wire to make your own electromagnet?

2a. What would you like to use?

  1. Would you like to use different chemicals on plants to see what would happen to the plants?

2. Would you like to use a machine to measure your brain waves?
3. Would you like to use a Geiger counter to search for uranium?
4. Would you like to use the instruments in an observatory?
5. Would you like to use a radio that you could talk into yourself?

The Subject Matter Interests of Junior High School Students Are Diversified.

When completed the questionnaire was used by the author in determining the interests and past activities of 55 pupils in the Colorado State College of Education Laboratory School. These students were in seventh and eighth grade science classes and were divided by sex as shown in column 2 of Table I.

The tabulated results were found to contain a great deal of knowledge about the students. In computing the groups' interests in the five areas of science covered by the questionnaire, the number of affirmative answers to all the questions within each area were totaled. Table I shows the number of affirmative answers given to the topics within each area by the different groups of students.

Although the results show a slightly greater number of affirmative answers in certain areas for all groups, the preference for one area over another area is not great. Much greater differences, preferences for certain areas, were noted in the answers of individual students.

Boys and girls of both grades were very interested in activities that involved the area of living things. Boys in both groups showed more preference for matter-energy than for the human body, and conversely, girls were more interested in the human body than in matter-energy.

What Activities are of Interest to Students?

A comparison of the responses to the questions in the various activities revealed some worthwhile information. For instance it was discovered that many of the things in science which students are most interested in doing are things they have done most often in the past.

In the tabulation of activities in which students were most interested and had had experience, the number of affirmative responses to questions within the 36 parts were reduced to percentages of the total number possible (275). For comparison the activities were then tabulated separately and ranked. The results of this tabulation are given in Table II.

The relationship between activities encountered in the past and those of current interest can be seen by comparing columns 3 and 8. Six of the activities—hear, solve problems, study, work with, own, and see—ranked in the first half in both past and current interest.

Many educators believe that problem-solving activities are the means to better learning experiences in science. It is interesting to note that "solving problems" ranks high in both columns. The rank of "studying" in both columns 3 and 8 would imply that students do not mind studying. Perhaps their resentment to studying, apparent at times, stems from the topics studied and not primarily from the activity itself.

TABLE I

RAW SCORES OF AFFIRMATIVE ANSWERS WITHIN THE FIVE BASIC AREAS OF SCIENCE DIVIDED BY GROUP AND SEX

GROUPS	NO. OF STUDENTS	LIVING THINGS	THE HUMAN BODY	THE EARTH	THE UNIVERSE	MATTER-ENERGY
1. 7th-Grade Class	26	417	359	329	362	358
2. Boys	10	194	134	148	140	174
3. Girls	16	223	225	181	222	184
4. 8th-Grade Class	29	735	667	584	557	648
5. Boys	16	397	373	340	320	397
6. Girls	13	338	294	244	237	251
7. Group total	55	1152	1026	913	919	1006

TABLE II
RANK, NUMBER AND PERCENT OF AFFIRMATIVE RESPONSES TO ACTIVITY ITEMS

HAVE DONE					WOULD LIKE TO DO				
NO. 1	RANK 2	ACTIVITY 3	NO. 4	PER-CENT 5	NO. 6	RANK 7	ACTIVITY 8	NO. 9	PER-CENT 10
1	1	Solved problems.	177	64.36	1	1	Hear...........	193	70.18
2	2	Played with.....	172	62.54	2	2	Solve problems..	175	63.64
3	3	Seen...........	151	54.9	3	3	Study..........	172	62.55
4	4	Studied........	144	52.36	4	4	Use............	169	61.45
5	5	Heard..........	143	52	5	5	Find out.......	165	60
6	6	Worked with....	140	50.9	6	6	Work with......	164	59.63
7	7	Worked on class projects......	137	49.82	7	7	Own...........	153	59.27
8	8	Taken apart....	134	48.73	8	8	Discover.......	161	58.54
9	9	Owned.........	133	48.36	9	9	See............	160	58.18
10	10	Asked questions.	129	46.91	10	10	Go.............	158	57.46
11	11	Wondered......	126	45.82	11	11	Read..........	154	56
12	12	Found out......	121	44	12	12	Ask questions...	153	55.64
13	13	Discovered.....	121	44	13	13	Take apart.....	151	54.9
14	14	Read..........	119	43.27	14	14	Play with......	147	53.45
15	15	Gone..........	116	42.18	15	15	Explain........	138	50.18
16	16	Used...........	108	35.64	16	16	Work on class projects......	134	48.73
17	17	Explained......	89	32.36	17	17	Wondering.....	126	45.82
18	18	Given reports...	83	30.18	18	18	Give reports....	108	35.63

Activities involving the giving of reports have not been experienced extensively nor are they of interest to the students in this group. The ranks of past and current activities may be a cause-and-effect relationship or it may not. The wise teacher, however, may well take such indications into consideration in planning classroom exercises.

The Teacher Should Provide Opportunities For the Satisfaction of Students' Interests.

From the results of this sample use of the questionnaire, a number of conclusions can be drawn concerning the way junior high students should be instructed in science. The almost equally indicated interest in all five areas of science shows that the science curriculum should be highly diversified for this level. In keeping with this concept, the science taught at this level should, and can, form the broad background of concepts upon which later study in senior high school and college science courses will enlarge.

At this age, future scientists can be developed. There is cause for grave concern among our scientists and statesmen who realize that the nation is far short of having an adequate number of trained scientists, scientific technicians, and science teachers. In this day of rapid scientific development the shortage of scientific personnel has serious implications.

A probable cause for it can be found in the past teaching of science, especially at the junior high school level. For too long, science has been taught as groups of facts to be learned and laws and principles to be memorized. All of which may be necessary, but they are not *as such* extremely interesting to children. Too, the activities in which students engage while studying science may well influence their opinion of science as a prospective occupation. Science classroom activities which are dull and uninteresting will certainly not develop a liking for future study or work in scientific fields.

It appears then that it is up to science teachers to alleviate this situation. We at least partially realize the importance of present science teaching to the quantity and quality of future scientists in our nation. Further, all members of our highly technical, modern society, regardless of occupation, are in constant association with science. They must be given the opportunity to engage in experiences which will help them take their places as members of a scientific society.

What is the correct way to go about it? One way has been outlined here. By using the natural interests of students, we can offer them more meaningful experiences in the fields of science. The result will be a better understanding of, and more interest in, science on the part of the students.

To accomplish this, we must know their interests. One of the methods which can be used to determine interest has been mentioned here.* There are others, perhaps some of them better. The importance lies not in *how* the interests of students are determined and *how* they are used in the classroom but that they *are* determined and used.

Opportunity in Junior High School Science

HARRY CRESSMAN

Supervisor of Science, Hicksville School District, Hicksville, New York

(NOVEMBER 1960)

In conversing with young people both in science classes and outside of science classes, a strong feeling persists with me that many pupils are ready for meaningful experiences in science far sooner than we may have been accustomed to suppose or to demonstrate in practice. Further, I am convinced that they are desirous and capable of more intense knowledge and greater depth of understanding of the natural laws which control their environment.

This conclusion undoubtedly is not peculiar to me, but rather is or has been an experience of many people, both teachers and nonteachers. What may make this strong opinion unique with me is that for the past two and one-half years, I have been in a position to determine whether or not there is any validity to the fact that pupils in junior high school are capable of doing more.

In September 1957, a pilot science program was organized in the public school system of Hicksville, New York, to determine what these meaningful science experiences might be; to select those scientific concepts which pupils at various grade levels could follow; and to demonstrate those natural laws which could be learned without the experience of frustration and failure in exploring new ideas. At the same time developing and/or strengthening desirable attitudes toward science is a part of the program. In short, we were interested in trying to determine as objectively as possible and in a real teaching situation what can be taught, to what grade level it can be taught, and to what depth we should try to teach it.

The first phase of the program for a general chemistry course began with selected groups of fourth- and seventh-grade pupils. A serious and sincere attempt was made to select those pupils whom we thought could profit most from this experience. Consequently, we used all the available information and what we felt was the most pertinent data about the children in making the selections. The criteria used were the intelligence quotient, reading and arithmetic ability, past scholastic record, teacher comments, parental consent, and finally and most important, the pupil's interest and willingness to participate in the program.

At the elementary school level, the plan was to start with a group of fourth-grade pupils and continue with them through the fifth and sixth grades. This group completed their phase of the program in June 1960.

At the junior high school level, the plan was to start with a group of seventh-grade pupils and continue with them through the eighth grade. This group of junior high school pupils completed their program in June 1959. The following information pertains to them.

TABLE I

Number of Pupils in Program	*Boys*	*Girls*	*Totals*
At Beginning of Seventh Grade	42	27	69
At Beginning of Eighth Grade	28	18	46
At End of Eighth Grade	28	18	46

TABLE II
Abilities of Selected Students

General Ability of Pupils Selected for Program		*Boys*			*Girls*		
		Median	Q_1	Q_3	*Median*	Q_1	Q_3
Intelligence Quotient	Quit Program	122	120	128	115	114	127
	Completed	129	122	136	122	119	131
Reading: Vocabulary	Quit Program	1.9	1.7	2.5	2.2	2.0	2.5
	Completed	2.4	1.8	3.5	2.2	1.4	2.5
Reading: Comprehension	Quit Program	2.4	2.0	3.0	1.8	1.8	3.0
	Completed	2.3	2.3	3.0	2.3	1.8	3.0
Arithmetic Reasoning	Quit Program	1.5	.9	1.8	1.1	.7	1.4
	Completed	1.8	1.6	2.5	1.4	.7	1.9
Past Scholastic Average	Quit Program	91	90	92	90	90	93
	Completed	92	91	93	93	93	94

The number of pupils who began the program in the seventh grade represented 7.2 per cent of the total seventh grade. The number of pupils who completed the program at the end of their eighth grade represented 7.1 per cent of the total eighth grade. Due to a decrease in the eighth-grade enrollment the percentage remained about the same.

The drop-outs are accounted for in the following manner:

1. Eight pupils dropped out of the program within the first month of the program in the seventh grade because of conflict of interest and scheduling of his fifth major subject.
2. Seven pupils moved from the district.
3. Four pupils dropped out because of loss of interest in the program.
4. Four pupils dropped out because they found themselves in a program beyond their abilities.

Incidentally, since this subject constituted a fifth major subject for these pupils and was not needed to complete their junior high school program of studies, they were permitted to drop the chemistry at any time and for any reason. Significantly enough, in spite of this freedom to remain a part of the study, only eight pupils chose to drop out and this was done during the first year of the two-year program. All who started the more difficult second year of the program persisted to the end.

The figures used in connection with the vocabulary, comprehension, and arithmetic reasoning were determined at the end of the sixth grade and refer to the number of years above actual grade placement in these areas.

Intelligence quotients were obtained from scores on the California Mental Maturity Test. Reading and arithmetic achievements were determined from scores on the California Reading and Arithmetic Achievement Tests.

The body of scientific knowledge classified as general chemistry was chosen as the content for the program, both at the intermediate and junior high school levels. During the seventh grade of the two-year program, pupils were instructed in that science content which we thought gave them the necessary background and attitude toward the proposed course content of the eighth grade. During their eighth grade, these pupils were then exposed to a general chemistry course as outlined in the Chemistry Syllabus of the Bureau of Secondary Curriculum Development of the New York State Education Department.

While engaged in the chemistry course during their eighth-grade studies, pupils were subjected to the same rules and regulations as any senior high school pupils who were taking chemistry for New York State Regents credit. They attended a chemistry class once a day for fifty minutes, five days per week, and a one-hour laboratory period once a week after school hours. Moreover, this laboratory period was conducted in the chemistry laboratory of the senior high school, several blocks away from the junior high school. Here, these pupils used the same facilities, equipment, and materials as the senior high school chemistry pupils. During their eighth grade, the pupils in the program spent the same amount of time in recitation and laboratory as the senior high school pupils. They used a recognized senior high school chemistry textbook and laboratory manual-workbook combination. Incidentally, all of this was in addition to their normal junior high school program of four major and several minor subjects.

At the completion of the program, results were evaluated in terms of the American Chemical Society

TABLE III

Test Form	*Groups Compared*	*Number of Pupils*	*Median*	Q_1	Q_3	Q_3-Q_1	*Range*
N	Eighth/ /Group A	44/ /523	93/ /50	83/ /25	96/ /75	13/ /50	62-99
	Eighth/ /Group B	44/ /3265	88/ /50	76/ /25	95/ /75	19/ /50	43-99
	Eighth/ /Group E	44/ /7164	89/ /50	78/ /25	94/ /75	16/ /50	47-99
1959	Eighth/ /Group A	44/ /590	92/ /50	87/ /25	95/ /75	8/ /50	66-99
	Eighth/ /Group B	44/ /3597	85/ /50	73/ /25	91/ /75	18/ /50	35-99
	Eighth/ /Group E	44/ /8202	86/ /50	75/ /25	92/ /75	17/ /50	38-99

Chemistry Examination and the New York State Regents Chemistry Examination.

Results on the American Chemical Society Examination

In June 1959, forty-four pupils took the American Chemical Society examination, Form N and Form 1959, according to instructions accompanying these tests.

Table III contains a comparison of the performance of the eighth-grade pupils with Groups A, B, and E of the Test Norms on the American Chemical Society Examination, Form N and Form 1959. (Percentile ranks compared.)

Incidentally, part of the group took Form N first; the remainder took Form 1959. All pupils took both forms of the test. The coefficient of correlation between the eighth-grade scores on Form N and Form 1959 was .95.

Group A consists mainly of juniors, with a few sophomores and seniors, who have had zero to two semesters of mathematics prior to taking the test. The nation-wide returns cover public and private schools.

Group B consists of juniors only having four to six semesters of mathematics but no physics prior to taking the chemistry course. Again nation-wide returns cover both public and private schools.

Group E consists of a random sample from the total nation-wide returns on the American Chemical Society Test, public and private schools.

Results on the New York State Regents Chemistry Examination

On June 17, 1959, forty-four pupils, along with the senior high school chemistry pupils, took the New York State Regents Chemistry Examination. They wrote their examinations according to the same rules and regulations. Their papers were scored, and, along with the senior high school chemistry papers, were sent to the New York State Education Department in Albany to be rechecked. The marks remained as originally recorded with the exception of three papers. On these papers the score was increased by a point in one case and lowered by one and two points, respectively, in the other two cases.

Table IV contains a comparison of the performance of the eighth-grade pupils with the pupils throughout the State of New York who took this New York State Regents Chemistry Test on June 17, 1959. (Test scores compared in Row A. Percentile ranks compared in Row B.)

TABLE IV

Test Form	*Groups Compared*	*Median*	Q_1	Q_3	Q_3-Q_1	*Range*	*Row*
June 1959	Eighth/ /NY State	80/ /76	75/ /65	90/ /85	15/ /20	30-98	A
	Eighth/ /NY State	75/ /65	64/ /40	90/ /84	26/ /44	?-99	B

Circled scores indicate the lowest passing test score and percentile rank. Coefficients of correlation between the eighth-grade scores on the American Chemical Society Test (Group B), Form N and Form 1959, respectively, and the New York State Regents Chemistry Test were .77 and .72.

On the basis of these two tests, one which permitted us to compare the eighth-grade group with chemistry pupils across the country and the other which permitted us to compare these same pupils with chemistry pupils across the State of New York, half of the eighth-grade pupils did better than 85 per cent of the students who took the Form 1959 American Chemical Society Test and better than 75 per cent of the students who took the June 1959 New York State Regents Chemistry Test. Thirty-nine of these pupils qualified for New York State Regents credit in chemistry.

Finally, if interest and self-motivation as evidenced by participation in class and laboratory work are criteria for determining readiness for a subject, then these pupils were definitely ready. If performance on nationally recognized examinations in chemistry is a sufficient and acceptable indication of a pupil's capabilities in the subject, the scores achieved on these tests by almost the entire group proved that a significant number of eighth-grade pupils are ready and able to pursue the study of chemistry to a much greater depth and a much broader scope than is or can be done in a general science class. Moreover, eighth-grade pupils can perform on a level with senior high school pupils in current courses of study in senior high school chemistry. Why not give these pupils the opportunity, at every level, to go faster and farther in a science program worthy of their interests and abilities?

This Is the Way We Do It

ELOISE T. HADLOCK

Coordinator, Elementary and Junior High School Science, Ithaca City School District, Ithaca, New York

(SEPTEMBER 1958)

THE purpose of this paper is to convince teachers of general science that a meager amount of laboratory equipment does not necessarily hamper gifted students interested in gaining skill in scientific problem solving. It is further intended to show that improved laboratory work gives the students the satisfaction and insights that come from experiences with handling equipment and utilizing the scientific method. Thus we are encouraging more young people to consider careers in science and engineering.

For some time the science teachers in our school had felt that our science curriculum was not sufficiently challenging to our groups of high ability. This opinion was shared by the mathematics department. In May of 1956, we carefully studied mathematics and reading scores obtained from the Iowa Basic Skills Tests and those obtained by a New York State School Survey Test in General Science. It was concluded that of 350 students in grade seven, there were 60 students who could profit by an enriched program in eighth-grade science and mathematics. The proposed program [1] was outlined for two high ability groups of 35 persons. The students relayed the plans to their parents, who were encouraged to call the faculty and guidance department for further details. At the end of a two-week period, sixty of the students signed up for the course.

Time and Materials

The standard curriculum for grade eight was designed for a twenty-week term. To lengthen the course to forty weeks it was necessary for the students to be excused from Language Skills.

Our laboratories are equipped with movable tables, but without gas, electricity, and water supplies at each table. The science storeroom which adjoins the laboratories was pressed into service, giving us six gas outlets, eight electric outlets, one hot water and two cold water connections. We have a total of three compound microscopes, and three triple beam balances.

Methods

No new units were added to the curriculum. The emphasis was on laboratory techniques, creative activity, critical thinking, and problem solving. A class of thirty students was subdivided into five groups. Group "A" learned to use microscopes, and to prepare temporary and permanent slides; Group "B" worked with measurements, learning how to use balances and became familiar with the metric system as applied to length, volume, and weight; Group "C" studied scientists and scientific methods; Group "D" surveyed career possibilities in the fields of science and engineering; while Group "E" worked on individual experiments, suggested by "Things of Science" and various science books. At the end of a two-week period, a test was given to

CHICAGO PUBLIC SCHOOL PHOTO

PHOTO BY LELAND JR. HIGH SCHOOL, CHEVY CHASE, MD.

each group and the students moved into a different group. The shifting from group to group continued until each student had experienced the five areas. The group change involved learning by doing to one of learning by reading, and then to another of doing. Each time the students moved to a different group, the student leader also changed thus giving opportunities to develop leadership ability in each student.

The class decided that there should be guest speakers representing the five major sciences. After polling the interests of their classmates, members of the group arranged for the speakers. [One speaker was Dr. Noah Kassman, a practicing physician in our community, and another was Dr. Hans Bethe, of Cornell University, who spoke on the source of the sun's energy.]

Another phase of the program was a study of science principles. Lists of suggested biological, physical and chemical principles were provided. Each student chose one for careful study, and later presented a report to the class.

More than half of the members of the class prepared projects and exhibited them at the district Science Fair. One of the girls earned a First Award with her stained and preserved chick embryos.

Results

While participating in the program the students prepared bulletin boards, listed Nobel Prize winners in chemistry and physics, listed modern scientists and their area of work, displayed collections, and took their projects to the elementary schools in the city where they explained them to members of the science clubs in grades four, five, and six.

At present these students are in ninth-grade science class with the same classmates and the same science teacher of last year. The curriculum for them is that planned for other ninth graders, but with the gifted group taking more initiative in directing class activities through teacher-pupil planning, preparing projects, attending lectures at Cornell University, watching television programs, and becoming the leaders in club programs. Four members of the group have assigned themselves set hours in the science stock room to help teachers in the department.

Both students and parents have been so favorably impressed by the program that two more eighth grade groups are participating in a similar program this year. Next year we will have four groups of eighth graders following the program.

The high school science department plans to keep the sixty students separate from other students who have had a different background. It is hoped that since all are college-bound that their choice of electives will make it possible for them to remain with the same group of the past two years. Their records will be carefully noted and their choice of careers will be observed and followed up wherever this is possible.

Making the Most of Experimental Exercises

ELLSWORTH S. OBOURN

Specialist for Science, U. S. Office of Education, Washington, D. C.

(NOVEMBER 1950)

COLLECTING and testing evidence by experiment is perhaps the most specific thing that sets science apart as unique in the whole field of learning. Scholars in the history of science commonly date the rise of modern science from the classic experimental work of Galileo and his contemporaries. The masters of science who have followed Galileo down through the years have frequently attained their enviable positions because of a resourcefulness in the ability to devise ways of testing the truth or falsity of hypotheses.

In the experiment, the science teacher has at his disposal one of the most potent devices of learning ever devised by the mind of man. There is some evidence to support the contention that science teachers at the ninth-grade level are not fully aware of the potentialities of the experiment as a device of learning and therefore use it ineffectively. In other science subjects the few experimental exercises in which control factors are now used is testimony to the inadequacy of the experiment as an effective device for learning.

Since teachers generally seem to teach the textbooks which are selected for their courses, it may be true that textbook writers will have to revise their conception of the nature and purpose of the experimental exercise before much can be done toward improvement in the science classrooms over the country.

The true function of an experiment is to furnish evidence bearing on the truth or falsity of some factor, the influence of which is being tested. What do we mean by evidence? One of the best statements directed toward an answer to this question was made by Henshaw Ward some years ago in the Harvard Teachers Record. He wrote:

> Science cares only for indisputable evidence. If the evidence is conflicting, science balances the probabilities without running headlong to a conclusion. Unless the evidence so cumulates that almost all competent observers are forced to agree, science suspends judgment! How salutary it is for any one of us to learn to suspend! Whenever new evidence appears the true scientist welcomes it; he is as ready to have his previous theory demolished as to have it corroborated. He is guided by a curiosity that cares only for what the new evidence indicates. Science recognizes that no amount of evidence is ever absolutely certain, that no knowledge is everlasting and immutable.
>
> The teacher who can give his class even an inkling of what true evidence is has made their intellectual lives safer and better. . . . If he tries to expound the abstract principle, he will accomplish nothing. He can convey understanding only by putting before the class one concrete illustration after another, and so gradually bringing out the difference between empty "thinking" and real proof. The humbler the demonstration the better.

The measure of a good experimental exercise is not easy to define. There are several criteria which can be applied all or in part. Among such criteria the following would be found:

1. Is the purpose of the experimental exercise stated clearly as a question?
2. Is the variable factor or hypothesis to be tested clearly identified?
3. Are the control factors identifiable? Are they adequately provided for?
4. Are the directions clear and concise?
5. Do the directions permit some latitude for the pupil to use his initiative and resourcefulness in planning and devising or are they "cook bookish" in nature?
6. Is the conclusion to be reached by the experimental exercise closely related by logical pattern to the stated purpose?
7. Is provision made for identifying the assumptions that are basic to the acceptance of the conclusion?

There is some evidence to indicate that teachers of ninth-grade general science present a large portion of the experimental work by the demonstration method. This is in no way a condemnation of the demonstration technique. If any criticism may be made, it lies in the fact that most teachers fail to make any differentiation between true experiments and demonstrations. Either all work preformed at the demonstration table is "experiment" or "demonstration." The thoughtful teacher will see that an exercise used to illustrate the application of some science principle is a much different situation from one used to test hypotheses.

The evidence available at the moment would seem to indicate that many teachers of science do not seem to be aware of the general principles which apply to good experimentation. These have been well summarized by Blough:

1. Experiments should be conducted in such a way as to make pupils think.
2. Children should be conscious of the purpose for performing an experiment.
4. In so far as possible, children themselves should perform the experiments, working as individuals or groups.
5. Many times, children can suggest experiments to answer their own questions.
6. Experiments should be performed carefully and exactly.
7. Pupils should learn the value of controlled experimentation.
8. Simple apparatus is more appropriate for use in experiments in the elementary (and junior high school) than complicated material.
9. Pupils should exercise great caution in drawing conclusions from experiments.
10. As many applications to everyday life situations and problems as possible should be made from an experiment.

The role of assumptions in accepting or rejecting conclusions is perhaps one of the most neglected elements in the teaching of experimental exercises. Many of the ideas accepted as truth are based upon assumptions, implied or stated. It would seem that more attention might be given in experimental procedures to the identification and evaluation of the assumptions which are basic to the conclusions reached.

As an example, consider an experimental exercise which might be a part of any course in ninth-grade general science.

The Elements of a Fertile Soil

Purpose: Do some kinds of soil bacteria help plants to grow?

Directions: Secure two pots of soil from a field in which good crops of clover or beans are growing or have recently been growing. Heat the soil of one pot to 130° F. and keep it at that temperature for 20 minutes in order to kill the bacteria in the soil. Then plant in each pot some seeds of clover and beans. Keep both pots well watered and in good growing light and temperature. When the young plants are a month old, what difference can you determine in growth and in root conditions?

Conclusion: Some kinds of soil bacteria do aid the growth of plants.

The acceptance of this conclusion rests upon certain things that are taken for granted as true (assumptions). Among these are the following:

1. The soil in which clover or beans grow contains bacteria which aid the growth of plants.
2. Heating to 130° F. for 20 minutes kills the soil bacteria.
3. Soil bacteria are the sole cause of the differences produced in growth and root structure.
4. The seeds used in each pot had the same rate of germination.
5. Clover and bean seeds will germinate, and their plants will grow, in soil which has been heated to 130° F.
6. One month is sufficient time to determine a difference in growth and in root structure of plants in the two pots.
7. A temperature of 130° F. does not break chemical compounds in the soil into elements or other compounds which aid the growth of plants.

These assumptions would seem individually necessary and collectively sufficient to the acceptance of the stated conclusion. In teaching experimental exercises in any science subject, it is very essential that consideration be given to the identification and evaluation of the assumptions which underlie the conclusions reached.

Teachers who are interested in utilizing the maximum of potential values of the experimental exercise for promoting the growth of pupils will be observed doing some of the following things as they teach:

1. They will let the pupils propose and define problems for laboratory study.
2. They will let the pupils frame the purpose of the experiment.
3. They will let the pupils propose hypotheses.
4. They will let the pupils identify the control and variable factors in the experiment.
5. They will let the pupils plan the controls.
6. They will let the pupils make the observations.
7. They will let the pupils interpret the evidence.
8. They will let the pupils formulate the conclusions to be reached.
9. They will let the pupils state the assumptions that are basic to the acceptance of the conclusion.

The Functional Approach in General Science

EMILE C. FONSWORTH

Chairman, Science Department, Yates High School, Houston, Texas

(FEBRUARY 1954)

A number of science teachers have found out through study of the problem that learning in general science can be made increasingly interesting and appealing through use of a variety of classroom approaches to the same study problem. Some, on the other hand, have been slow to let go of the fact-cramming techniques so popular in days gone by. There remains that lurking fear of missing certain "vital and fundamental" content as the change is made from the lock-step procedure to one involving simply inquiry by individuals or groups of pupils. Science teachers who have tried an individual or small group approach have been convinced that skill in use of the scientific method can best be achieved in classrooms where content is wide and varied. Under the stimulus of the appeal through novelty and interest, students can be encouraged to cover more science work than they usually cover in the logical subject matter approach. In a multiple approach the way is opened for the introduction of problem-solving methods, for sharing experiences, for promoting working relations, and for developing skills in choosing alternatives. Furthermore, the problem-solving approach with students can make subject matter more functional and meaningful.

This article contains a brief description of how a science instructor led his junior high school class to the realization of some of the values of the problem-solving approach. This group had already some science experiences in connection with their activities in the elementary grades, where they studied the home and community. In their first quarter of general science they had studied astronomy in order to get a better understanding of the place of the earth and the solar system in the universe. In the second quarter, they planned with the teacher to explore some of the more formal divisions of physics by working on certain selected problems. The students were motivated in their choices by the felt need for developing better understandings of certain principles encountered in their earlier work with machines and scientific gadgets found in their own environment. It was decided that the problems selected for study would be confined to the four broad areas: (1) how certain electronic devices work, (2) what laws govern the operation of machines, (3) what principles of light control the working of optical instruments, and (4) what energy conversions take place in the internal combustion engine.

The class of thirteen students was then divided into four groups, with each group selecting an area and each member within the group assuming responsibility for a project or a part of a project. It was agreed that group members would first master their individual work, and then make a report, with demonstrations, before the whole class; after which a test made out jointly by the teacher and the group would be administered to the class. The following progress report written by one of the students will help make clear the nature of the group attack:

> After the class consented that our group would be permitted to work on machines, which we were plugging for, we then decided among ourselves who was to work individually on inclined planes, pulleys, or levers. We then went to the library to get some starting information on our topic. After we had read we wrote out a guide sheet and bibliography for the class, and then we made plans for our own individual projects. After working through our projects and checking on the reading done by the whole class, we began to report and make demonstrations. The class got so interested that they set up other problems on machines and worked through them with the help of our group.

By the end of the third week group reporting and demonstrating were well under way. The group on electricity gave demonstrations with magnets, motors, vacuum tubes, and radio sets. They used charts and moving pictures to clarify concepts about the nature of electricity and the working of electrons in television. The group on the gas engine used a working model that had been made by a previous class to demonstrate the gas engine cycle. The principles of energy change and transfer were explained by the use of moving pictures followed by discussion. The group on light added novelty by giving demonstrations with a telescope borrowed from a hobbyist and by arranging for a work period in the University Spectroscopy Laboratory.

This work took up only seven weeks of the time. But the teacher foresaw this possibility of short-term projects during the planning session. The class readily accepted the suggestion of using whatever time remained within the quarter to work on individual projects of their own choosing. The selection of individual projects began in the eighth week. Although a few students selected their projects without help, it was necessary for the teacher to present a number of suggested projects, to help students make choices in terms of value to them, and to discuss ways of working them out. But during the eighth week, all students but one selected a project, went ahead planning it with the aid of the teacher or some other available resource person, and settled down to the job of working it out under guidance. Their projects included setting up a balanced aquarium and terrarium, dissecting frogs and studying physiological effects, building a periscope, work in table-top photography, making projection prints, studying the characteristics of vacuum tubes, purifying water, and the fractional distillation of petroleum. It was clear that all the work might not be completed by the end of the quarter, but the teacher's experience with other classes working in similar ways had indicated alternative ways of continuing the work with satisfaction. Some projects could be carried home for completion or further work in student laboratories. Some students could come to the school to work on projects or look after experimental animals and plants during out-of-school days. In some cases, involving long and continuous work periods, students could spend the needed hours without interruption on interesting problems. And there was always the possibility of extending the work over into a new quarter.

The question arises as to the appropriate role of the teacher when a science class works this way. The truth is that his is no easy task. He may expect to expend more than the usual amount of energy due to the demands of new kinds of duties. The success of the class work depends upon a large amount of planning, both in and out of class, especially at the beginning of activities. Students must be helped all along, both in and out of class, in executing their plans successfully. Even though the children are allowed to choose their problems and projects, a large variety of materials and suggestions must be available to stimulate their thinking and imagination. It is the responsibility of the teacher to take the leadership in providing a rich and challenging environment. Audiovisual aids must be selected and secured at the proper time. Reports, demonstrations, and tests must be prepared and checked. These call for time and energy both in and out of class. Yet the work within the actual class is made no easier, because of the variety of activities going on at once. The teacher must move from group to group, even from individual to individual, each with a different problem or difficulty. He must keep up with the progress of all and render assistance wherever and whenever needed. He must be on the alert for lagging interest, find out the cause, and renew the interest.

The teacher's responsibility extends beyond his own classroom. Although librarian, shop teacher, and resource persons cooperate in helping the students with their work, the science teacher is primarily responsible for the success of the whole venture. Students in general science find it necessary to work in various laboratories and places because of the differences in their types of work. The science teacher must be sure that they work intelligently and within limits of safety. But with careful planning and stimulation both teacher and pupil can acquire the discipline and the skills needed for carrying on simultaneously a variety of interesting and novel learning activities.

Teachers who try this approach to the study of general science must not expect too large returns at the outset. They must be patient and willing to work hard in helping students discover new values and new skills necessary for success in functional approaches. Students will need much help in building rich experimental backgrounds, and this task, while not easy, usually pays increasingly large dividends as the work proceeds. It will be found necessary to stimulate students and make them eager to attack their own problems, to accept cheerfully the responsibility for planning, thinking, and working that accompany such self-imposed tasks, and to build within themselves a driving consciousness of high standards of excellence.

The quality and the nature of work done in a permissive and cooperative atmosphere depends upon a number of factors. The amount of science already studied will certainly increase the fund of information available for new work. But the ways and methods of previous science study are perhaps far more important. Under proper guidance and provision for science study through the grades, students can bring to general science in the junior high school an amazing zeal for studying science as well as a very rich background upon which to draw. There are many examples of elementary school teachers who are using excellent approaches to the study of science as experiences in their total activities. The children are encouraged to choose problems, to plan their attack under the direction of the teacher, and to select and organize data upon which to base conclusions which are tested in action. The elementary science program in many cases now includes the community as a laboratory, and science projects are being set up for study in the classroom.

The general science teacher in the junior high school who receives children with these rich experiential backgrounds must accept a new challenge. He must be ready to nurture their zeal, interest, and skills by affording a wide variety of exploratory activities into all the sciences without regard for the outmoded limits set for conventional courses. His charges must be freed, and he must be prepared for the new responsibilities of larger content and improved methods. Where elementary and junior high students are still denied these novel and stimulating ways of studying science, the general science teacher as the key-man in the science program has an even larger responsibility. His immediate job is to help his students to overcome their deficiencies and to gain the more useful competencies. His long-range responsibility is to accept the leadership in working for sound changes in the elementary and junior high science programs. He must work untiringly to help other teachers to discover value in directing students to study science through problems that hold interest and meaning for them, and he must also help other teachers gain the competence needed for success in such an approach.

Reading in Science as a Means of Improving the Junior High School Program

CLYDE M. BROWN

Assistant Professor of Education, Southern Illinois University, Carbondale, Illinois

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THE objectives of elementary school experiences, says Glenn O. Blough in his book, *Elementary Science and How to Teach It*, have been stated by all kinds of educators in all kinds of ways but that the most important purpose might be phrased: "to help children gain the ideals, understandings, and skills essential to becoming good citizens." What Dr. Blough has said for the elementary school holds true also for other levels of education.

We say that the study of science should help boys and girls develop command of scientific generalizations or principles which they can use in solving the problems of their environment. Also, we feel that the study of science should help pupils grow in their ability to solve their own problems more effectively. Too frequently, in trying to help children learn to solve problems, we adults hand down our adult conceptions of the problems of youth for treatment, rather than utilize the experiences of the boys and girls. As teachers we should enlist the aid of our students in finding the problems to be treated and then help them to get the information needed to arrive at better understanding. This should be a "doing" rather than a "telling" activity.

The science program provides children with countless problems that are of real concern because they are near at hand problems that possess a fascination because they are so intimately associated with young lives. The experiences which junior-high-aged boys and girls have today come to them in many ways and are world-wide in scope. Avenues for direct and vicarious experiences have widened immensely since the war. Consequently the formalized junior high science programs built around static subject matter outlines are so confining that it is difficult to keep the interest of students and really meet their needs.

Science teachers feel that their students' understanding of our changing environment demands a comprehension of some basic principles and laws of science. But unless these laws and principles are set in modern dress, teachers will have difficulty in getting them across to students. As teachers, we are aware of the areas in which the science needs in general education lie. If we establish such concepts as "The Earth's Surface is Constantly Changing" and "Man Has Put the Forces Of Nature To Work" as areas around which our students' activities shall be centered, then their interests can be utilized in directing the way in which the basic ideas may best be presented.

Teachers complain that the students do not read; i.e., they do not read the text assignments and they depend more and more upon the class presentations for their understanding of the basic fundamentals. Competition from radio, moving pictures, and, in particular, TV programs is cited as a reason for poor response to preparation of assigned textbook reading. Checks upon out-of-school activities have repeatedly shown that children in areas served by TV spend more hours per week watching programs than they spend in school and in preparation of school assignments.

Checks made in science classes in the University School at Southern Illinois University show, however, that boys and girls do read quite a bit. One class of fourteen students listed forty-four magazines from which they read more or less regularly. The boys read from twenty-four magazines and the girls from twenty-one, with several being used in common. While a number of these magazines might not receive the stamp of approval of science teachers as reputable sources of science information, they are those which carry the burden of presenting the scientific materials—good, bad, or indifferent—which are presented for public consumption.

In their reading statements the junior high students frankly admitted the reading of comic books. To the boys those presenting scientific and pseudo-scientific ideas of space travel and explorations have a great appeal. Science fiction stories have a large following and are avidly read by their fans of both the junior and senior high school levels. Our young readers are impressionable and to a certain degree gullible consumers of materials presented to them. We as science teachers need to assist them in distinguishing truths, half-truths, part-truths, and no-truths that they come upon in their reading.

Utilizing the motivating influence of the radio, TV, motion pictures, comic books, and science fiction offers a challenge to the science teacher. Since a function of education is "to help boys and girls do better the desirable things they will do anyway," we must learn to utilize these programs and these readings to enrich our classes and to create a demand on the part of the students for reliable information to use as a measuring stick for evaluating what they hear, see, or read.

Several methods which seem to have possibilities for utilizing those ideas seen, heard, or read for the enrichment of the junior high science program may be suggested:

1. Clearing House Program

Devote class time at regular intervals to free discussions of questions which the pupils have. This is not necessarily just a period in which the teacher will hand out answers, but it will provide an insight into the kind of data the children are seeking. The teacher need not fear to say, "I do not know," in such a program but should be able to "help" them as groups or individually to find satisfactory answers. The breadth of his students' interests will amaze one who has not yet tried this technique of enriching his program.

Should the open question period just suggested prove too broad and unwieldly, a modification might be tried in which a student committee would call for written questions and choose those questions which seem to be of most universal interest for use in the class discussion period. The questions of more limited appeal can be dealt with individually.

2. How and Why Club

Boys and girls are naturally curious individuals, and science can provide them with the opportunities to find out the "How's" and "Why's" of their environment. They can be encouraged to read in their quest for *answers to their questions* rather than to read for just *facts*. They should be encouraged to question data presented to them and to determine the authority by which an author arrives at the assumption he propounds. In science classes we can help by providing reliable, authoritative sources for our students in a classroom library, the central school library, or a reference shelf.

3. Science in the News Program

As an incentive to spur reading of science materials in the current publications, a regularly scheduled session in which the pupils report upon science articles read from newspapers and magazines is suggested. Discussions can lead to more discerning and observant readers and broaden the general information available to the whole group. Details as to frequency of session, length of reports, and desirability of follow-up research can be worked out with the groups. By stressing search for materials related to the general area being dealt with in the more formal part of the class work, more than incidental learning can be achieved.

4. Written Reading Reports

An organized free reading program can be coordinated with the "Science in the News" program by having the students make brief written reports of their readings. More than just a synopsis of the information in the article is desirable. The pupil comments concerning the articles may prove the most pertinent value, as the comments encourage thinking about what is read.

5. Science Seminars

Science reading interests will tend to group the students. These interest groups can organize seminars for more intensive study and discussion. Time can be arranged for the meetings during study or club periods, or after school. Facilities and guidance for experimenting should be provided if the groups' activities indicate a desire and need. Guidance for individual interests can be provided in such a program in special cases. Care should be exercised to see that the activities are pupil motivated and purposeful, with the teacher functioning as a guide and a counselor.

6. The Experimenters

Utilize pupil planned demonstrations and group experimentation to enliven the text and reference readings concerning science problems. The textbook provides common information for all that may be expanded by parallel reference readings by the better and/or more inquisitive students. Problems will be presented, and pertinent facts may need a supporting demonstration. The students in their discussions can determine where verification by experimenting is needed and may plan the activity.

7. Recreational Reading from Library Sources

Children who select and read books for pleasure seldom realize that science teachers classify some that they read as science books and others as non-science books. To encourage a selection of good science-interest books there is a need for collaboration with the school or public librarian to establish a science shelf. We can develop the concept that there is a difference in reading for information and reading for recreation. Our pupils should also be encouraged to browse through the books on our science shelves before making their selections. Closed stacks in the library discourage many readers from making a varied selection and can retard wide usage of books in general.

Children like to talk about what they have read. Organization of a group of reading critics will help sell the reading of books to other students. By clipping brief written commentaries by the students into the library books which they have read concerning *their* opinions of the books and *their* recommendation of them to the other readers, an increased circulation may be encouraged.

In improving the program of science in the junior high school through a program of reading in science, we as science teachers need to help our students do better the desirable reading they are doing anyhow and to use the materials read as a motivating factor in our classrooms. Our students are already reading; they can be encouraged: (1) to read more widely varied materials; (2) to make a better selection of what they read; (3) to read more critically; (4) to make practical applications of the new ideas gained; (5) to share their reading experiences with others; and (6) to test their newly gained knowledge against authorities and by experimentation.

The Philosophy of Test Construction in Science

GEORGE W. ANGELL

President, State Teachers College, Plattsburgh, New York

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ANY TEACHER SHOULD BE CONCERNED with her class as a whole and the students as individuals. A good teacher is primarily concerned with the student as an individual, not only in relation to the other students in the class and to other similar students in the general population, but also in his strengths and weaknesses relative to his inherent capabilities. To aid the teacher in her appraisal of the individual are numerous standardized instruments of measurement, or the teacher may design and construct her own instruments to appraise particular characteristics of the student in his own situation. The all-pervading purpose of these tests is to make possible more accurate prediction and control in the educational process. The value of any test depends upon the extent to which the teacher has clearly in mind the answers to these questions:

1. What changes in behavior are desirable?
2. How can these changes be measured?
3. What aptitudes are essential to the development of a given form and level of behavior?
4. What are the crucial elements of the educative process?

The value of educational measurement depends upon the validity of the answers to these questions.

If we agree with Walter Cook of Minnesota, education has two main functions: the integrative and the differentiative. Within the limits of individual aptitudes, integrative education is designed to make people alike in their ideals, values, loyalties, virtues, language, and general educational and social adjustments. It is often referred to as general education. It unifies and gives cohesion to the social group. Differentiative education is designed to make people different in their competencies, to prepare them for the professions and specialties. The elementary school is concerned mainly with the integrative function and the high schools to a large extent; but at the college level, especially the last two years, any general education usually tends only to supplement professional and special education.

In those segments of the educational system where general education is emphasized, it is the obligation of the teacher to adapt her teaching, and, if you will, her subject-matter, to the aptitudes and abilities of her students. In order to achieve this, she should know:

1. the general scholastic aptitude of the student
2. any outstanding specific aptitudes the student may have
3. the student's general personality pattern
4. the student's particular interests and hobbies
5. the student's environmental situation, past and present
6. the relative strengths or weaknesses of the student in the basic skills
7. (if the teacher is teaching in a secondary school) the relative strengths or weaknesses of the student in the teacher's particular subject area

A combination of currently available standardized tests may be used to throw considerable light on the basic nature of the individual student, his current educational status, and his potentialities for further development. There are three general types of tests: achievement, diagnostic, and prognostic. Since the three types of tests are more alike than they are different, let us consider the use of instruments designed to measure in the area of achievement.

In using an achievement test, a teacher will ideally test her class in the fall to determine the educational status of the class as a whole and of the individual student as well. In light of these pre-test results she will design her course for the year. Throughout the year she will test at frequent intervals to learn whether growth is taking place, whether she is doing an adequate teaching job, and whether her selection of course-content is meaningful. At the end of the year—as a summary measure—she will administer a final examination. This may well consist of two parts: a standardized test, so that she may compare her class with a national—or system-wide—standard, and one part which she has designed to measure those concepts and abilities she has stressed and which are not covered by the standardized test, or are not in the same balance in the standardized test as they were given in her classes.

Although the teacher, in the belief that the ultimate goal of teaching is to aid in the maximum development of the individual student's inherent capabilities, may have endeavored to teach in such a way as to develop a range of abilities rather than to dwell solely on factual recall, the tests available to her are concerned almost completely with informational background. How, then, is the teacher who has tried to develop in her students such abilities as the ability to reason quantitatively, or to evaluate the claims of others, to evaluate her teaching? Admittedly, the problem is not an easy one, it is not insoluble.

Recently the staff of the Cooperative Test Division of the Educational Testing Service decided to try to develop a battery of articulated tests in the areas of academic ability (i.e., aptitude), English composition, listening, reading, mathematics, social studies, and science for four levels—grades 4-6, 7-9, 10-12, and 13-14. Each level test was to be articulated with adjacent level tests so that a continual growth measure could be obtained over the period of grades 4-14.

The first problem was to determine what should be measured in each area. A panel of eminent science educators was appointed to define the scope of the tests in science. Since the needs of the general student are all too often ignored in many present curricula, the committee agreed that the tests should be constructed to measure the educational outcomes of a theoretically ideal course for general students in the overall area of science. The implicit assumption was that *all* students should have been taught those important concepts in the several areas of science which have significance for the well-educated person in understanding and dealing with his environment. An ideal curriculum should be designed in such a way as to develop in the student, not only an understanding of the significant concepts of science, but the ability to use his knowledge as a responsible member of society. The committee agreed that the tests must be constructed with attention given to three different dimensions: first, the aspects of the influence of science upon society; secondly, the abilities which should be developed through adequate science teaching; and third, the basic concepts and understandings of each of the sciences.

It was recognized that each of the aspects of the influence of science upon society involved numerous problem areas; for example, the economic aspects of science involved such problem areas as conservation, industrial application of science, mining and fuels, and agriculture. After considerable discussion the committee agreed upon four major aspects of science: economic, cultural, social, and an around-the-home, or practical aspect.

The committee also agreed upon six abilities which, they felt, should be developed through adequate science courses. Inherent in each of the abilities was the ability to apply scientific knowledge to familiar or unfamiliar situations. This, in essence, is what the tests were designed to measure—the ability to use scientific knowledge to solve problems. The list of abilities was as follows:

1. *Ability to identify and define a scientific problem*

   Included within this category is the ability to isolate a problem from a mass of given material and to formulate the problem in a way which allows for systematic solution.

2. *Ability to suggest or screen hypotheses*

   Sub-abilities here include the ability to suspend judgment, the ability to recognize cause-and-effect relationships, the ability to recognize the possibility of testing an hypothesis, the ability to recognize the logical consistency and plausibility of an hypothesis, and the ability to check it with relevant laws, facts, operations, or experiments.

3. *Ability to select validating procedures*

   This encompasses the design of experiments and planning the collection of appropriate data.

4. *Ability to interpret data and draw conclusions*

   This includes the ability to formulate valid conclusions and to recognize or draw generalizations from data known or given.

5. *Ability to evaluate critically claims or statements by others*

   This encompasses the critical evaluation of advertisements, written materials, and audio-visual materials. Also included is the ability to detect superstition and fancy, and to recognize the pseudo-scientific and the use of unwarranted extrapolations or generalizations. Other abilities here are the ability to distinguish among fact, hypothesis, and opinion, and the ability to distinguish the revelant from the irrelevant.

6. *Ability to reason quantitatively and symbolically*

a. To understand and use numerical operations
b. To understand and use symbolic relations
c. To understand and use information presented in graphs, charts, maps, and tables

This ability is essentially manipulative: interpretative aspects are included under ability 4. Thus, the ability to *read* information from a graph would fall into this category, but the ability to *interpret* or draw conclusions from the material presented in a graph would be classified under ability 4.

The third dimension, subject-matter, comprised the conventional areas of biology, physics, chemistry, meteorology, astronomy, and geology. The committee was particularly emphatic in indicating that only the most important concepts and understandings in each of the sciences should be measured.

In order to assure adequate attention to each of the three dimensions, the committee decided that each test should consist of sets of objective questions, each set being based on a single brief problem which would be presented verbally, graphically, or pictorially. Within any set should be questions measuring different abilities and involving different concepts. Each question should measure both a specific ability and a specific concept. The problem situation should be presented briefly but clearly, so that reading ability would not be too great a factor.

Two months after the meeting of the panel, a two-week workshop was held for the purpose of test-writing. Members of the workshop included the panel plus nine other teachers, so that there were three to four workshop members at each grade level.

It was recognized that the construction of test questions is a highly individual matter and that different writers use quite different methods. Generally, however, the best items are produced by first selecting situational material in the problem area in which it is desired to measure, and then selecting a specific ability and a specific concept related to the problem. The question is then written considering both ability and concept at the same time. This method tends to insure balance in the concepts and abilities measured. This was the method suggested to, and generally used by, the workshop members.

Among the advance materials sent to the workshop members was a list of some important concepts in science. It was suggested that perhaps the best way to use the list in writing individual questions was to select an appropriate concept directly related to a chosen problem situation, and to ask the question, "What is the important understanding inherent in this concept that I should measure?" Often there were several important understandings, and a number of understandings of only secondary importance, related to the concept. For example, having selected situational material in the problem area of conservation, and having decided to measure the ability to interpret data and draw conclusions, the writer might select the concept of chemical change for the focus of the question. However, the problem immediately arises as to what phase of the concept should be measured. Certainly the junior high school student should not be expected to know the difference between matathesis and simple decomposition, or the equations describing the decomposition of protein materials found in some organic fertilizers. The question might, however, be so phrased as to measure whether the student recognized that energy changes are involved in all chemical changes. It was, therefore, apparent that the list of concepts, though useful as an idea-source, had to be translated into terms of the particular important understandings before it was usable for actual inclusion in questions.

One outcome of the two-weeks workshop was the production of nearly twelve hundred questions in over one hundred twenty sets. Each set and each question was carefully reviewed by each level committee in terms of appropriateness of abilities, concepts, and aspects, and technically for ambiguities and level of reading difficulty. These test questions have been pretested on a sample of students at each level drawn from the general population. Those questions which have been found acceptable by the committee and which, in addition, have proved to be statistically sound are being assembled into final forms. These tests will be normed in the spring and will be available in the fall of 1956.

To make clear what the committee had in mind, and the way in which they implemented their ideas, here are two example sets of questions, one from material written for the junior high school level, and one from the material written for the senior high school level.

ILLUSTRATIVE TEST QUESTIONS

Aspect of Science: Economic

Grade level: 7-9

Questions 1-4

A farmer had a farm consisting of fifty acres of hillside land and fifty acres of level land. He wanted his farm to be as productive as possible.

1. After a heavy rain the farmer found a gully forming on the hillside land. The most likely reason for the development of the gully was that the
   (A) ground was bare of vegetation
   (B) farmer had plowed the ground in furrows
   (C) farmer had planted deep-rooted crops
   (D) soil was too rich

2. When the crops were growing the farmer noted that in some areas of the fields the plants were greener than in others. He asked several neighbors why this had happened. The following explanations were given. Which one is the most probable?
   (A) Those parts which were greener had been sprayed with insect poison.
   (B) The greener areas had received more fertilizer than the other areas.
   (C) The greener areas were drier areas.
   (D) The greener areas were more closely seeded.

3. The farmer had heard that some soils were acid and some were alkaline. He decided to test his soil by shaking some soil in a container with distilled water and then testing the mixture with litmus paper. The best way to choose the soil to be tested would be for him to select
   (A) several samples from various parts of the field
   (B) a sample from the lower end of the field
   (C) a sample from each corner of the field
   (D) samples from sandy areas only

4. The farmer decided that he would use next year's crop to enrich the hillside soil. The best procedure would be to
   (A) plow the ground very deep before planting
   (B) plant deep-rooted crops
   (C) plant oats and cut them as a hay crop
   (D) plant clover and plow it under

Aspect of Science: Economic

Grade level: 10-12

Problem area: Conservation

You are the engineer directing a new dam project on a certain river. You have a team of scientists, i.e., biologists, chemists, geologists, meteorologists, and physicists in assistance on the project. You have to locate the dam in the best position, and arrange for the hydroelectric power and the irrigation of the surrounding district, which is a semi-arid region. The water level is to be about 300 feet above the river.

Subject-matter area: Geology

Concept: Diastrophism

Ability: To identify and define a scientific problem

Of the following the most important problem requiring your attention would be
(A) to find the point where the river banks come closest together
(B) to find the point where the largest and deepest lake could be built up behind the dam
(C) to investigate the characteristics and structure of the rocks underneath the river bed and along the banks
(D) to determine the least amount of inhabited land that would be flooded

Subject-matter area: Chemistry

Concept: Chemical change

Ability: To interpret data and draw conclusions

Which of the following might most logically be produced near the dam?
(A) Aluminum
(B) Sulfuric acid
(C) Gasoline
(D) Pig iron

Subject-matter area: Chemistry

Concept: Acid-base reaction

Ability: To interpret data and draw conclusions

Part of the water is used for irrigation. A sample of the water from the river is mixed with a sample of soil, filtered, and concentrated. The resulting solution turns red litmus blue, has a bitter taste and a soapy feel. Which of the following conclusions is justifiable?
(A) The soil is acidic.
(B) The soil is alkaline.
(C) The river water is alkaline.
(D) None of the above conclusions is justifiable.

Subject-matter area: Meteorology

Concept: Water cycle

Ability: To suggest or screen hypotheses

The Weather Bureau in a nearby city has predicted that within 5 years after completion of the dam the average yearly relative humidity will have increased markedly. This increase might be due to all of the following EXCEPT
(A) transpiration from nearby field-crop plants
(B) evaporation from the man-made lake
(C) evaporation from irrigated soil
(D) evaporation from the excess water overflowing from the dam

Subject-matter area: Biology

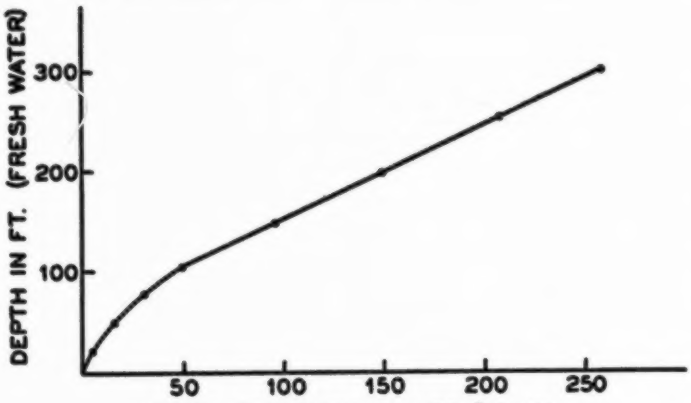
Concept: Photosynthesis

Ability: To suggest or screen hypotheses

Green aquatic plants growing at the bottom of the river will be covered over with 300 feet of lake water. They will probably die due to
(A) lack of light
(B) lack of mineral salts

(C) lack of oxygen
(D) excessive water pressure

Subject-matter area: Physics
Concept: Hydrostatics
Ability: To interpret data and draw conclusions



The above data were obtained during the summer from Lake Melville which is 20 miles shorter in length but approximately the same depth at the dam as the proposed design. Lake Melville is located in a nearby region. On the basis of the data given, which of the following conclusions is correct?

(A) The pressure exerted by a liquid varies directly as the depth.
(B) The water near the surface of Lake Melville is warmer than the water below.
(C) The graph would be a straight line if the measurements had been accurately made.
(D) The length of the lake affected the pressure at the surface but not at the bottom.

In the first set, the situation as posed in the two-sentence introductory statement is clearly an economic aspect of science within the problem area of conservation. The first question was designed to measure the student's understanding of the functions of vegetation in minimizing erosion and also his ability to interpret data and draw conclusions. The second question was written to measure the student's understanding of the role of fertilizers in plant development together with his ability to evaluate critically the claims or statements of others. The third question was written to measure the student's understanding of the principles of adequate sampling techniques and also his ability to select validating procedures. The fourth question was written to measure the student's understanding of one of the basic principles of crop rotation and his ability to screen hypotheses. While it is true that most of us could read and answer these questions with little, if any, critical thought processes—in fact, in most cases, we would answer these on a factual recall basis—it is thought that the junior high school student will not be able to do this and in most cases must answer the questions through the use of some basic information plus application of the problem-solving abilities.

The second set of materials was especially written for the purpose of illustrating to the members of the workshop the test design envisioned by the original panel. While the junior high school set we have just examined contains items measuring almost exclusively in the area of biology, the set we are about to consider was particularly designed to cover a wide range of subject-matter areas, concepts, and abilities; in some cases, it may appear that one or more of the items have been "drawn in by the heels" but it must be borne in mind that this particular set was especially written to illustrate the range of subject matter, concepts, and abilities which might possibly be drawn in to an appropriate situation. The problem situation is clearly conservation and certainly falls within the economic aspect of science. The first item, on the face of it, is certainly measuring the student's ability to identify a scientific problem and in order to understand this problem the student must have some understanding of the practical results of diastrophism, although it is certainly not necessary either that he know the term diastrophism as such, or that he even understand the process of diastrophism. The other five questions are also quite clearly written to measure the abilities and concepts noted for each.

To those of us who designed and wrote these tests, it seems that this is the desirable direction in which measurement should proceed: paralleling the best teaching practices and measuring the development of the critical skills and abilities as taught by the most capable teachers.

The main points of this paper can perhaps be summarized in the following statements:

1. Measurement, one phase of evaluation, is an integral part of effective teaching, and enables the teacher more accurately to appraise the student's educational status, his educational potentialities, his interests, and the teacher's own effectiveness.
2. Tests, both teacher-made and standardized, can be constructed to measure the outcomes of "abilities teaching." Such tests should be based upon a clear and explicit statement of purpose and objectives and test questions should be carefully written to fit these specific objectives.

Importance of Earth Sciences in the Curriculum

GATES WILLARD

Science Teacher, Manhasset Junior-Senior High School, Manhasset, L.I., New York

(APRIL 1961)

IT MIGHT BE INTERESTING to conduct a poll which would request a vote on the relative importance of two scientific fields such as geology and chemistry. The results would vary widely according to who was replying. Understandably, the views of chemists and geologists could be expected to be somewhat prejudiced! On the other hand, a geochemist might have a mental breakdown while trying to weigh separately two sciences which he imagines to be mutually supporting. After all, virtually every "chemical" studied by man comes from the crust of the earth. The science teacher might cast his vote according to the kinds of experiences he has had. If, for example, his college geology course was uninspiring, he may favor chemistry. Yet he surely is aware that the earth is important to him. Literally, where would he be without it? Eventually, the high degree of inconsistency in the replies would probably cause the poll to be abandoned.

Which is the more important part of an automobile engine—the carburetor or the fuel pump? The question is absurd the absence or failure of any of a number of components would prevent the engine from running. The scientific enterprise includes

from running. The scientific enterprise includes

many interrelated and interdependent areas. Is it any more logical to vote upon whether some fields of science are more important than others?

In this era of constantly changing school curriculum there is mounting pressure to include more and more science. The schools, however, can hope to include only morsels of the vast fields of science which are expanding far more rapidly than curriculum. Is there really justification for adding geology, astronomy, meteorology, and related sciences to an already overcrowded school program? Are any of these areas *important* enough to *replace* something that is presently included?

The Curriculum Problem

How is school science subject matter chosen? Decisions are frequently made about what should and what should not be part of the program. Most persons involved in science curriculum planning are specialists in biology, chemistry, physics, or combinations of these. If there were no room in their professional training for courses in geology, astronomy, or meteorology, would these people attach importance to the teaching of earth science areas?

In many schools, the earth sciences have been treated to some extent as a minor portion of general science. However, there are a number of more sophisticated principles and concepts which might better be developed at a higher level. Why are high school students deprived of experience with these? The traditional high school science courses continue to be biology, chemistry, and physics. Usually there is a syllabus which effectively keeps the teacher on a straight but narrow path. Teachers often claim that there is more than enough material in their own subject areas. Why should they even consider introducing fields which are unfamiliar to them? Perhaps

Ninth graders including boys and girls at Manhasset have a serious approach to their laboratory work.

these teachers are unaware of the strong relationship of the earth sciences to biology, chemistry, and physics.

What the Earth Sciences Can Do for the School Science Program

The subject matter of any science course should not be considered apart from the methods by which it is taught. *Any* science may be presented in a descriptive, and unchallenging manner. The earth sciences can be dynamic and vitally interesting, and problem-solving techniques may be used at least as readily as in other science courses. Moreover, some unimaginative teachers have presented earth science as a glorified story about the landscape with a little practice in rock identification from a key. Perhaps some constellations were memorized, and students learned how to read a weather map. Many a teacher has been unable to transfer depth of understanding to his students because his own formal training in the earth sciences has been lacking or incomplete. This is not an uncommon malady among chemistry, physics, biology, and general science teachers, but because earth science is a relative newcomer to the schools, the problem is particularly acute.

Since there appears to be a lack of awareness of the potentialities in earth science teaching, the balance of this article is devoted to a discussion of what the earth sciences can do for the school science program. A few specific examples are listed below:

1. The earth sciences are environmental in scope.

1. The earth sciences are environmental in scope.

The student can develop greater understandings and appreciations of his natural surroundings. Local field trips can yield important information about the geologic history of an area and man's use and misuse of his natural resources. Brief trips to the schoolyard itself can reveal weathering and erosion at work. Students can see that natural forces are changing the earth today as in the past.

2. Interest in the principles of light and optics can be aroused when they lead into a study of the heavens by means of a telescope. Students are intrigued to discover how radiant energy from outside the earth is practically the only source of information about the universe.

3. Depending upon the location of the school, certain ecological projects may be undertaken. For example, the relationship of ancient as well as modern marine life to the physical environment may be studied in fossils or marine forms found on the beach.

4. In an introduction to minerals and rocks, many important chemical concepts can be emphasized. Students learn the value of determining physical and chemical properties with accuracy in identifying minerals. By studying and growing crystals similar to those found in rocks, students can learn far more about the behavior of atoms, molecules, and ions than a mere discussion could impart.

5. Earth science is of strong current interest. The impact of the International Geophysical Year is only beginning to be felt, and it is not necessary to elaborate here upon the need for space education. Strontium 90 in the atmosphere, the oceans as mineral resources, conservation of natural substances, and searching for new material are topics of vital concern.

6. There are numerous opportunities for club and hobby activities. Students can build their own weather instruments to record data on atmospheric changes. Those who are ambitious may want to construct telescopes, grinding and polishing their own mirrors. Mineral, rock, and fossil collecting are hobbies that can be maintained throughout life, and an inexpensive lapidary unit provides a source of pleasure for those who want to polish stones and make their own jewelry. This activity is enjoyed equally by boys and girls.

7. Earth science draws heavily upon biology, chemistry, and physics. An excellent medium is provided for demonstrating the *interdependence* of science fields. There is hardly a principle of physics that cannot be applied to the dynamic earth and other bodies of the universe. Virtually every substance used by man comes from the earth. The theory of evolution is based upon fossil evidence. It is interesting to note that most geology majors are required in college to take at least one year each of chemistry, biology, and physics in addition to their geological training.

8. There are excellent opportunities for integration with other courses. The tie to geography is obvious. Natural resources, the effects of climate upon the world's inhabitants, the dangers of atomic radiation, and the impact of new earth science discoveries upon society are topics which are treated in social studies as well as in science classes. Various types of models and visual-aid material may be constructed in art and shop classes.

8. There are excellent opportunities for integration to geography is

9. With increasing emphasis upon laboratory experiences, the earth sciences have a great deal to offer. In addition to the outdoor laboratory, much can be accomplished in the classroom. A few subjects which may be investigated are listed below:

1. Reflection and refraction of light.
2. Determination of chemical and physical properties in minerals.
3. Identification of minerals by means of specific gravity.
4. Properties of water.
5. Principles of crystal growth.
6. Nature of solutions.
7. Evidence of evolution in fossils.
8. Gravity.
9. Map making.
10. Bernoulli's principle.
11. Transfer of heat.
12. Soil chemistry.

13. Construction of weather maps.
14. Acceleration.
15. Action-reaction.
16. Centrifugal-centripetal forces.
17. Determination of weight of air.

Finding a Place for Earth Science

If an earth science course could be a worthwhile part of the curriculum, what would be replaced? If earth science is put in, something will have to go. General science seems ripe for change. There are several reasons for disillusionment with it—particularly at the ninth-grade level.

1. Students become bored with "general" science year after year. This is particularly apparent in schools having a successful elementary science program. In the ninth grade, specialization in mathematics and language is common. Aren't students ready for a less "general" science course?

2. General science is usually a hodgepodge of unrelated information taken from too many areas to permit study of anything in depth. Today students are learning about insects, and next week they will study atomic energy. How will they ever discover the interrelationships of scientific disciplines? What is general science? It defies definition! What guides are used to decide the areas that should be included?

3. There is a decided tendency for repetition of subject matter from year to year since general science usually skims lightly along the surface, barely touching upon a multitude of units and never treating any of them in detail.

4. Where can teachers be found who have a broad knowledge of many growing science fields? Some general science teachers are trained only in biology, chemistry, or physics. Many general science teachers are not well trained in any science field. What *is* the best training for a "general" science teacher?

5. How is it possible to plan what is to be taught at the various grade levels considering the diverse training, experiences, and abilities of teachers? What happens to the program when teachers leave the school system?

In some states such as Pennsylvania and New York, ninth-grade earth science is replacing general science in an attempt to solve problems such as those listed above. In the new course, it is possible to relate the earth to its atmosphere and the universe. With this unifying thread it offers a distinct advantage over the usually conglomerate "general" science. A small number of science areas are explored in depth so that students have a better opportunity of finding out what science is really about. Repetition and duplication are avoided. The course is unlike what is being taught at higher as well as lower levels. With depth of study, laboratory experiences are particularly important. Students can develop skills in handling basic equipment needed also in biology, chemistry, and physics. The course provides excellent training for students who will take other science courses. Teacher education is simplified. The ninth-grade earth science teacher has definite goals for which to train. He can become a specialist in a few areas rather than knowing too little about too many subjects.

The Status of Earth Science

Pennsylvania and New York have large-scale, rapidly growing earth science programs, although much of the teaching is being done by under-trained but enthusiastic personnel. In New York where the course has been offered for many years, earth science is being recommended for gifted ninth graders, but much of the course can readily be adapted to the needs of most students. Some New York high schools offer earth science as an alternative to biology, chemistry, or physics, thus creating a fourth science elective. Several other states have initiated or are contemplating earth science programs.

In anticipation of the growth in earth science teaching, the National Science Foundation is supporting the American Geological Institute in the development of earth science teaching resources. During the summer of 1959, twenty geoscientists and ten teachers assembled at the University of Minnesota in Duluth for the purpose of considering concepts of course content and cataloguing, evaluating, and developing teaching materials. Since the Duluth conference, preliminary copies of the sourcebook have been undergoing testing by 100 teachers in selected areas throughout the United States. At present the materials are being revised and edited in preparation for publication in 1961.

Three earth science textbooks are on the market. A fourth will enter the field early in 1961, and at least one more publisher is planning a text.

Someday, earth science may well achieve a status in the schools equivalent to that of biology, chemistry, and physics. As a new kind of course, it does not have to fit a traditional pattern. Any school that is searching for a *different* kind of science course would do well to investigate the advantages of instituting earth science.

Earth Sciences in the Ninth Grade

LOREN T. CALDWELL

Head, Department of Earth Sciences, Northern Illinois University, DeKalb, Illinois

(OCTOBER 1958)

THE curriculum committees of most public school systems are taking a critical look at their present science program. The science-learning experiences of the last several years in the first twelve grades have failed to recruit a satisfactory number of students into the sciences as a profession. It is an immediate and urgent problem that school curriculum committees, school administrators, and science teachers determine and correct the weaknesses in our science programs. This feeling of disatisfaction with our science program extends through the elementary schools, the junior high schools, and the senior high schools. Dissatisfaction seems to be most intense in the junior high school and particularly in the ninth grade where general science courses have been most commonly offered. Many school systems are hunting for either a revision of their general science program or a new sequence of learning experiences which might challenge the growing mind of the ninth-grade student in such a way that the student can see the significance of continuing to study in selected fields of the sciences.

Our problem today in the sciences, as they are taught in the public schools, is to let science exhibit its full potential to the student as a force toward good. The beneficent applications of science should be given a clear field to reduce the forces toward war. The public school science teacher must help the teen-age student to see that study of the sciences helps to strengthen the disciplines of the great humanities. This task of the ninth-grade science teacher is made easier when selected earth-science concepts are taught: such as units from the areas of weather, climate, astronomy, geology, and the physical and social aspects of geography. These units should be taught in such a way that they would illustrate the natural applications of laws from physics, chemistry, and biology. By this curricular approach, a study of science can be shown to be one of man's most powerful and noble means for searching out truth and for elevating man's dignity by augmenting his understanding. The misapprehension about the nature and purposes of science as a force toward war may be one of the factors underlying the current shortage of scientists.

Dr. James R. Killian, Jr.,[1] Special Assistant to the President for Science and Technology stated in his Introduction to "New World's of Modern Science," as follows:

> "I do think the evidence is clear that in the secondary schools science teaching has suffered more than teaching in any other field. . . . ."
>
> "Another condition which calls for better public understanding of science is the impact of science on public policy and the impact of public policy on science . . ."
>
> "Clearly, the makers of public policy and the citizens they represent need as never before, to increase their understanding of science. . . ."
>
> "We have urgent need of more scientists . . . . who can build bridges of understanding between the domain of science and the domain of nonscience. We need a growing body of exposition to make science and scientific activity understandable to laymen."

Dr. Killian's statement that we need more scientists who can build bridges of understanding between the domain of science and the domain of non-science serves as a basis for my recommendation that basic concepts from the earth sciences of astronomy, meteorology, conservation, geology, and geography be employed in organizing a year of science for the ninth grade. If we wish to build a bridge between the domain of science and the domain of non-science there is no better way through the scientific method than to find the study units which give natural earth phenomena where laws from physics, chemistry, and biology may be applied, and where man's reaction to natural earth phenomena may be observed. This will make possible a scientific approach to understanding many social behavior patterns on this earth. With such understandings of natural causes for social patterns, the social studies can be helped to become social sciences.

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[1] James R. Killian, Jr. "New World's of Modern Science." Dell Publishing Company, New York, 1956. p. 15.

Some assistance should be furnished in this article to those science curriculum committees attempting to make such revisions in their science program. If such a reorganized program is being undertaken for the first twelve grades, this writer suggests that lists of basic concepts desirable for being taught in the secondary school are available from the United States Office of Education. Three studies[2, 3, 4] have been made in determining those lists of basic principles (concepts) for each of the fields of physical science, biology, and earth sciences. Selections of basic concepts to be taught may be made and related reading materials secured from references.

The earth-science principles made available by curriculum research may be employed by organizing a science curriculum for the ninth grade. From the field of the earth sciences, 332 principles (concepts) of the earth sciences were derived from many public school sources of information. Of these principles, 126 were judged to be related primarily to the area of geology, 75 to the area of physical geography (including weather and climate), 75 to the area of astronomy (including space science), and 56 to the area of the scientific aspects of conservation. Based upon the independent ratings of a jury of nationally known science educators, 117 of these principles (concepts) were rated (13-15) as highly desirable in a scale of rating from 1-15 for use in determining curriculum content in the grades from 7-12 inclusive.

Many bibliographic guides are available[5] to curriculum committees in the development of literature graded to the student, in the organization of information about the basic concepts which have been selected for study. This approach does not prohibit but rather invites the use of teaching methods such as problem, project, or unit organization. This approach to curriculum organization indicates a specific list of purposes for studying science in the ninth grade.

Beginning a study of the earth.

There are very few Earth Science textbooks published at present which are designed to furnish a satisfactory course outline and the associated data to meet current needs placed by the public and world situations upon the ninth-grade science program. There is however an abundance of literature[6, 7, 8] written for the ninth-grade student from the concepts of earth science. In most school systems, some outside assistance is needed to help in the organization of this literature for curriculum construction and for use in the ninth grade. Many national science organizations are urging that teams of capable science supervisors be made available through some central agency (such as an Office of Public Instruction) to school systems in need of science curriculum reorganization. It is probable that this assistance should begin with the ninth-grade science program. This would imply that among the science supervisors to be made available to the school systems, a proportionate share of these supervisors should have training and experiences in all of the earth sciences.

The task of correlating the basic sciences such as physics, chemistry, and biology with the social sciences certainly falls within the areas of the earth sciences. Since the science program of the elemen-

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[2] Caldwell, Loren T. "A Determination of Earth Science Principles Desirable for Inclusion in the Science Program of General Education in the Secondary School." Doctor's Thesis, School of Education, Indiana University, Bloomington, Indiana, 1953. 198 p.

[3] Martin, W. E. "A Determination of Principles of the Biological Sciences of Importance for General Education." Unpublished Doctor's dissertation, University of Michigan, 1944.

[4] Wise, Harold E. "A Determination of the Relative Importance of Principles of Physical Science for General Education." Unpublished Doctor's dissertation, University of Michigan, 1941.

[5] National Research Council, The American Geological Institute. "The Earth For The Layman." Publication 2101, Washington, D. C., 1957. (Reference to literature in the earth sciences separately listed for elementary school, junior high school, senior high school, college, and adult reading.)

[6] Namonwitz and Stone. "Earth Science." D. Van Nostrand Company, Inc., New Jersey 1953.

[7] American Association of Secondary School Administrators. "Conservation Education in American Schools." 29th Yearbook, National Education Association, 1951. (Give references for conservation of natural resources for reading and study from grade three through twelve.)

[8] National Council of Geographers. "Journal of Geography." Book Review Sections, *Graded Literature for Geography Bibliographic Lists*, 1953-58.

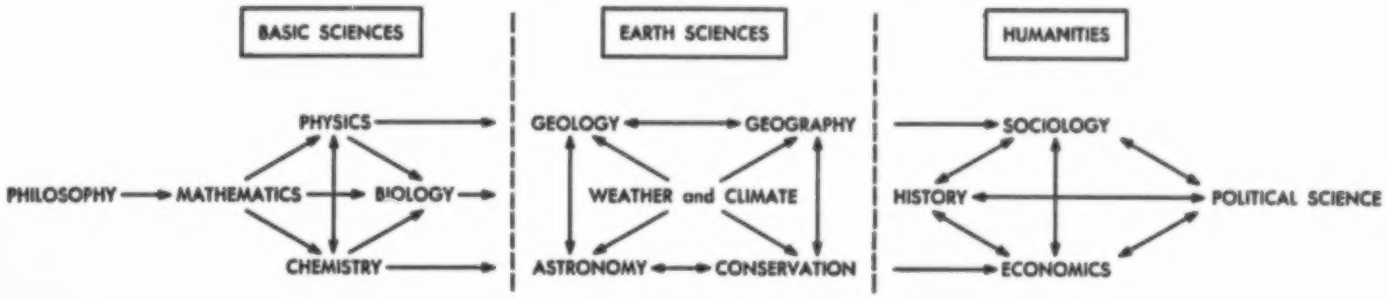

Diagram of Correlation Channels Between Scientific Principles, Earth Science Principles, and Social Principles

tary school is one dealing (largely) with the discovery of common scientific things around us, near and far, and the senior high school science courses deal largely with the specific concepts in separate special sciences on an elective basis, much importance is left to the aims and purposes of the junior high school science program. The task of tying the effects of the basic science world to the social world should be accomplished through the seventh, eight, and ninth grades. Normally much time is spent in the seventh and eighth grades to an awareness of the world distribution of things, conditions, and man. This leaves the ninth-grade student prepared to start that study of the earth sciences where the physical, chemical, and biological worlds are seen as causal factors in the social and economic and political world. This insight can be accomplished through a well-organized science program from the fields of astronomy, weather, climate, conservation, geology, and geography. Dr. Leonard Engel[9] can well be quoted here in this respect.

> ". . . the world that science deals with is a single world, however diverse its different faces appear. There is an intimate connection among the sub-worlds covered by the natural, the biological, and the social sciences. Each has its own laws: but living organisms also obey the laws of chemistry and physics; and man is at once a social phenomena, a biological organism, and an exceedingly intricate bundle of physical and chemical events."

This quotation indicates the need of specifically studying the relations between science and man through natural earth science phenomena.

In the accompanying diagram there has been an attempt to show how earth science principles may be correlated with factual data found in social principles. In this fashion, it is possible that earth science principles may be shown as functional guides for science teachers in building educational bridges between the concepts found in the earth sciences with resultant concepts found in the social principles of the humanities.

This bridging of these two fields of our culture may be one of the important services given by earth science principles when they are effectively used as guides to science teaching in the ninth grade of the secondary school curriculum. It is possible that such a curriculum could contribute to the validity of related basic social principles to be studied later. It has become evident to both the science teacher and science student that there are cultural values in relating scientific elements in our culture to their effect-patterns in the significant phases of our culture. When such patterns of relationships have been identified, evaluated, and put into operation in our public school curriculum, society should be in a position to more effectively solve its social, political and economic problems through education. Consequently, it is hoped that the science teacher may be permitted to make a contribution toward a more functional school curriculum with schools allowing abundant curriculum time for this task.

This new task for the science program in the public schools puts a greater burden of training and practice upon the science teacher. It becomes most essential that certification requirements for public school science teachers be adjusted to meet the training requirements of this new and essential task.

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[9] Engel, Leonard. "New Worlds of Modern Science". Dell Publishing Company, Inc., New York, 1956. p. 19-20.

Camping With Accent on Science

IRWIN SLESNICK

Science Teacher, The University School, Center for School Experimentation,
The Ohio State University, Columbus, Ohio

(FEBRUARY 1959)

OUTDOOR education through school camping programs has grown throughout the United States to the extent that in many regions it is considered an important ingredient of the on-going school curriculum. Coupled with the objective to enrich the physical education program with outdoor recreation is the aim to inspire wholesome conservation attitudes and practices. The University School at the Ohio State University, in order to better realize the latter objectives for its camping program, refined its 1958 junior high school field experience. The school administrators and the involved grade counselors requested that the high school science staff assume the major responsibility for organization of the instructional camp program.

It was generally agreed that in order for the students to gain a respect, an appreciation, and a knowledge of nature, fundamental details of nature embodied in specific disciplines should first be introduced to the students. Conservation was therefore to be taught inductively with six specific disciplines (entomology, botany, vertebrate zoology, ornithology, geology, astronomy) providing the material for concepts preparatory to the formation of conservation generalizations.

Seven weeks prior to the time when sixty-three of the seventh and eighth graders were to leave for camp, the science preparatory program was begun. Specialists in each of the above mentioned disciplines were scheduled to make an introductory presentation on Monday of each week. In each case, the specialist who made the presentation was the individual who later accompanied the group on the week's camping trip.

The first week of the conservation unit study concerned entomology. The "expert's" presentation did not attempt to cover the field but, rather, endeavored to excite and stimulate interest which the grade group utilized in the intensive work which followed. The entomologist spoke of the great diversity of insects, the many ways they affect man and the fascination of observing and studying the anatomy, physiology and the behavior of a single specimen. He showed the combined grades an extensive insect collection, an experiment in progress and the basic equipment of an entomologist. Throughout the presentation special studies were suggested and one common laboratory exercise with living specimens was assigned. He left with the grade teachers a list of available books, films and suggested field trips.

Each succeeding week a new field was explored. Again the natural history specialist, either from the University School staff or from the community, inspired the group with knowledge and spirit of, and reverence for, details in the design of nature.

During the final week before leaving for camp, each specialist made one appearance before the group to outline the nature of the field experience in his area; listing the equipment needs of each student and the needs of those students who were planning individual projects with his guidance.

The Future Farmers of America camp in the Ohio Muskingum Conservancy district had been selected as the 1958 campsite. The group arrived on Sunday, May 18, and stayed for five days. Students were previously assigned to study groups of about sixteen. The groups were designated A, B, C, and D. Soon after arrival on Sunday groups B and C met with the vertebrate zoologist who organized the trapping exercise preparatory to class work on the following day. As can be noted from the schedule (page 12) the astronomy group (D) assembled at 8:00. (The science staff with its equipment arrived at camp several hours before the students. They set up laboratories in the recreation hall and reconnoitered the area for the field work).

The ornithology and astronomy classes met formally for four days while classes in entomology, botany, geology and vertebrate zoology were scheduled for four sessions on Monday and Tuesday. The work of the class groups was thoroughly planned, yet the schedules were flexible enough to

Time	*Sunday*	*Monday*	*Tuesday*	*Wednesday*	*Thursday*	*Friday*
5:30		Reveille Bird Hike	Reveille Bird Hike	Reveille Bird Hike	Reveille Bird Hike	Reveille Bird Hike
6:00		Bird Hike A	Bird Hike B	Bird Hike C	Bird Hike D	Bird Hike (open)
6:30		Reveille	Reveille	Reveille	Reveille	Reveille
7:30		Breakfast	Breakfast	Breakfast	Breakfast	Breakfast and Pack Lunch
8:15		Inspection	Inspection	Inspection	Inspection	
8:30		Classes A. Geology B. Entomology C. Vertebrate Zoology D. Botany	Classes A. Entomology B. Geology C. Botany D. Vertebrate Zoology	Project	Project	Reports (9:30) Evaluation (10:30) Clean up
11:15		Recreation	Recreation	Recreation	Recreation	
12:00		Lunch	Lunch	Lunch	Lunch	Leave camp
1:15	(2:00) Leave for camp	Classes A. Botany B. Vertebrate Zoology C. Entomology D. Geology	Classes A. Vertebrate Zoology B. Botany C. Geology D. Entomology	Project	Project	
4:30		Recreation	Recreation	Recreation	Recreation	
6:00	Picnic	Dinner	Dinner	Dinner	Dinner	
7:30	Eve. Rec.	Eve. Rec.	Eve. Rec.	Eve. Rec.		
8:00	Astronomy D	Astronomy C	Astronomy A	Astronomy B	Reports	
9:00	Snack	Snack	Snack	Snack	Snack	
9:30	Get ready for bed	Get ready for bed	Get ready for bed	Get ready for bed	Get ready for bed	
10:00	Lights Out	Lights Out	Lights Out	Lights Out	Lights Out	

Finding live specimens.

A specialist prepares the group for field study and explains the proper use of instruments, and how to make observations in the study of Astronomy.

adapt to weather changes, "rare finds" etc. In botany, for example, each student planted a pine tree on a hillside, sought unusual flora, keyed out at least one tree and one wild flower, viewed the ecology of a north-south slope, noted relationships between kinds of plants and environment—yet no two class sessions were identical.

Throughout the planning period at school and the class sessions at camp the instructors were pointing out possible individual projects which could be undertaken during the four large blocks of time on Wednesday and Thursday. In many instances students had begun project work before arriving at camp. Most students had already identified the general field in which they planned to work. By Wednesday morning each student had met with an instructor to discuss the procedure he would follow during the two project days.

Typical of the projects undertaken were: a study of the biology of the tent caterpillar, observations of sun spots, geological mapping of the camp area, identification and lyrics of bird calls, and identification and casting of animal tracks. Several students who wished to specialize in all fields received much satisfaction from making a general natural science survey of a given small area.

Concerning Ninth-Year Biology

PHILIP GOLDSTEIN

Chairman, Biology Department, Abraham Lincoln High School, Brooklyn, New York

(DECEMBER 1958)

FOR many years, biology has been considered to be best placed in the tenth year of the science sequence, followed by chemistry and physics in years 11 and 12. Suddenly there is a great deal being said about moving biology down into the ninth year, in order to make room for more advanced electives in the twelfth year. It is becoming increasingly apparent that this idea is being fostered and pushed in certain quarters over the objections of many science teachers. Therefore, I should like to get my oar into this controversy before it goes much further.

But before I say my piece, I should like to make clear that I am no Johnny-come-lately to the field of science teaching. Nor am I a college teacher with little or no contact with what goes on in high school science teaching. I have spent the best 27 years of my life teaching biology and other sciences to assorted high school pupils in four New York City high schools (including six years at the Bronx High School of Science). In addition I have done a little college teaching on the side. For the last nine years, I have been chairman of the Biology Department at Abraham Lincoln High School in Brooklyn, N. Y. I am the author of two books which are used in many high school science classes, as well as an assortment of workbooks, articles, syllabi, etc., in the field of science teaching. One of my articles was awarded a first prize in the Science Teachers Award Program of NSTA several years ago, and on two other occasions I have been awarded honorable mentions.

And now that I have given my credentials, I hope that I have established my status as an expert witness. Therefore, I now feel ready to present my testimony. I would like to recount the events which led up to my being an unsuspecting pioneer in the movement for ninth-year biology, and then to draw some conclusions from my experience.

How I Became a Pioneer

Some time ago, my principal invited the two science chairmen of the school to meet with him on the question of what we could do for our outstanding science-minded students. He was interested in developing a super-duper science program for a small group of special students who would get more than just the usual four-year science sequence consisting of general science, biology, chemistry, and physics. After we had kicked various thoughts around for a while, I finally proposed a plan which met with the approval of the principal, the physical science chairman, the administrative assistant, the program committee, and powers that be.

Essentially the problem was one of program space. We already had plans for a course in experimental biology, another in laboratory techniques, one in college physics, and even a shop course for these special pupils. The big problem was how to squeeze them into an already loaded program which our bright pupils carry. My solution was simple. I urged that for these selected pupils who were going to take all the high school sciences anyway, we could very well omit the general science in the ninth

year and start them right off with biology. Then we could follow this up with chemistry plus experimental biology and shop in the tenth year, physics in the eleventh year, and that would leave the twelfth year open for college physics, laboratory techniques, or any other science electives that we could devise. And so, in all innocence, I became a pioneer in the ninth-year biology movement.

Of course these were bright pupils—hand picked. Every last one of them was highly recommended by previous teachers. Each applicant for the course had a high I.Q., a good reading score, a good arithmetic score, and a high standing on the Iowa tests, so there was little question about basic ability. On top of this we called meetings of the applicants for the course and their parents to explain that this was to be a difficult course which would require lots of work. And into the class finally went only pupils who wanted to become a part of this program, and whose parents agreed.

But then something else happened, which had no relationship to this special program, but which in retrospect takes on great importance. It was sheer accident, but when my teaching program was made up, not only did it carry this special ninth-year class, but also one of our regular tenth-year biology class, but also one of our regular tenth-year honor classes in biology. This class was also made up of bright students, but these were tenth-year students. So by the sheerest of accidents, a controlled experiment was set up. Here were two parallel classes made up of selected students, both being taught the same material by the same teacher, and both being tested at the end of the year by the same statewide Regents Examination. There was only one difference between the two classes. One class consisted of ninth-year pupils, while the other consisted of tenth-year pupils, so that there was an average age difference of one year.

What Happened

I had no idea at the time that I would want to compare ninth- and tenth-year biology. Therefore I kept no records to compare reactions of these two classes. However, certain subjective conclusions forced themselves upon me. These I will state later on in the article. But results on the New York State Regents Examination are a matter of record, and I can look back at this objective record and make comparisons. So, let us examine the Regents results of these two classes, keeping in mind that they both learned the same material under the guidance of the same experienced teacher (namely me), and that they both took exactly the same examination under exactly the same conditions.

To begin with, let us take a look at the distribution of the grades scored on the regents examination by the members of the two groups under consideration. These figures are presented in Figure 1 below.

DISTRIBUTION OF MARKS ON N.Y.S. REGENTS EXAMINATION IN BIOLOGY—JUNE 1958

Mark on the Regents Examination	Number Receiving This Mark			
	9th year class		10th year class	
100	0		1	2.6%
95–99	6	18.8%	17	44.7%
90–94	6	18.8%	11	29.0%
85–89	9	28.1%	5	13.2%
80–84	2	6.3%	2	5.3%
75–79	4	12.5%	2	5.3%
70–74	0			
65–69	4	12.5%		
35–39	1	3.4%		
Total	32	100.1%	38	100.1%
Mean	84.7		93.0	

Figure 1

Without recourse to any detailed statistical analysis it seems immediately evident that the 10th-year group did far better on this examination than did the 9th-year group. Just one look at the distribution curves of the two groups (Figure 2) will show this clearly. (Note that in the 9th-year curve, the case which fell between 35 and 39 has been omitted since it is so far off the curve that it is abnormal.) Since the number of students in the two groups is not equal, the curves are plotted in terms of per cent of the group getting a given mark on the regents examination.

Now consider the means of the two groups. The ninth-year group had an average score of 84.7 while the tenth-year group averaged 93.0. This gives us an average difference of 8.3 per cent in favor of the tenth-year group. Is this a true difference, or is it due to chance alone? To test this, we calculated the standard error of the difference and found it to be 2.4. The ratio of difference to standard error of the difference (8.3/2.4) is equal to 3.46. By reference to the appropriate probability table we can see that in so far as our groups are representative, and in so far as our test is valid, this is a true and reliable difference between ninth- and tenth-year groups. There is only one chance in 3600 that a difference in favor of a ninth-year group will turn up if this experiment is repeated.

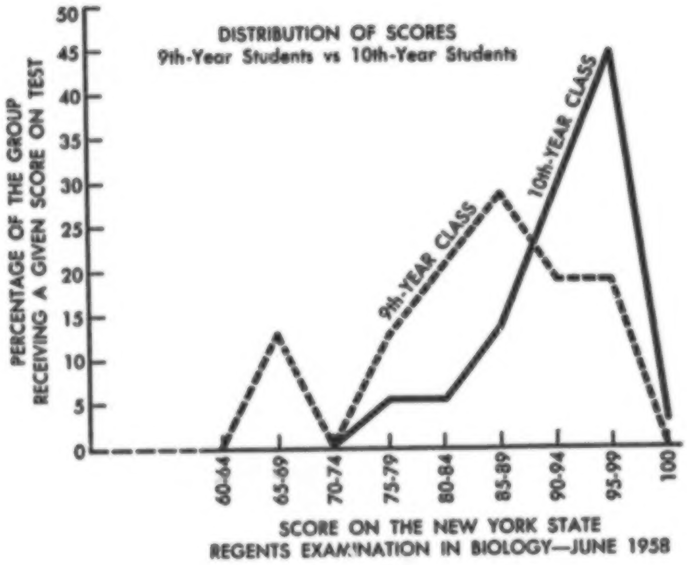

Figure 2

Next, compare if you will, the per cent of ninth- and tenth-year students that stand in the top half of the total group. Calculation shows the median score to be 91.6 per cent. By reference to figure 3, you can see at once that of the ninth-year group, only 10 students out of 32 (31.3 per cent) scored higher than the median score of the whole group. But in the tenth-year group 25 out of 38 (65.8 per cent) of the students stood above this median score. Thus more than twice as many tenth-year students are in the top 50 per cent of the group than ninth-year students. If we consider the top third of the total group the ratio is even higher in favor of the tenth-year students.

Observe just one more fact. About 15.6 per cent of the ninth-year group scored lower marks on the test than any one in the tenth-year group. This can be seen by referring back to Figure 1. All in all, from whatever angle these results are examined, there seems to be a significant advantage for the tenth-year biology student over the ninth-year one.

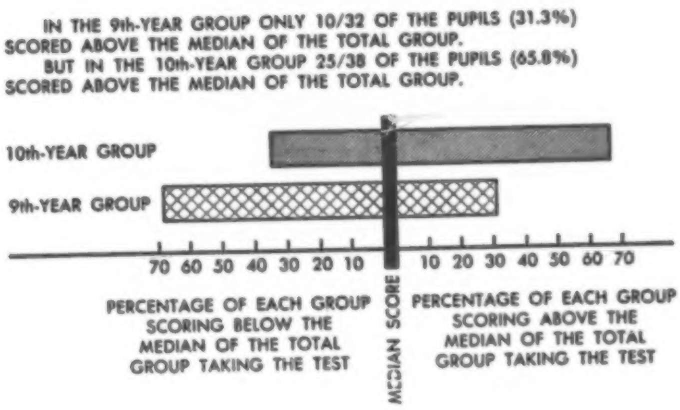

Figure 3

My Interpretation

I will grant immediately that this accidental experiment includes but a small number of cases. It needs repetition with larger numbers, and on a planned basis rather than as an accident. Still, the results are so surprisingly startling that they cannot be brushed off and overlooked. Frankly, as the marking of the June 1958 regents examination was completed, and as I first began to record the grades, I was horrified at the poor showing made by my selected ninth-year class. Their achievement on this test seemed far below the standards I have become accustomed to expect from honors classes. But a little mature reflection showed me that I should not have been so surprised. There were indications right along that everything was not as good as it should be. There were danger signals many times during the term—poor grasp of theoretical concepts, unsatisfactory approach to individual and group reports, and other such things. But I just wasn't looking for these danger signals.

I have reached the conclusion that although there is only one year difference chronologically between ninth-year and tenth-year students, the gulf which actually separates them is tremendous. The difference in maturity is much greater than the year difference in age. A boy or girl fresh out of elementary school at the age of 12 or 13 (and our bright pupils do reach ninth year at this age) is still figuratively a baby. But by the time he has spent a year in high school, he has grown tremendously—he has developed from a child into a teenager, with a completely new outlook and understanding. That year of maturation, experience, and growth makes all the difference in the world.

So, when I applied the same teaching techniques and procedures to this class that I have always used with honors classes, they were not really ready. They had not yet reached the state of maturity necessary for this approach to a subject. They were no more prepared for it than are our high school seniors when they suddenly change to college freshmen and face still another approach to learning. College teachers of freshmen will appreciate this.

Still, despite this lack of readiness, this special group was not so bad when the work was of a factual nature. They could learn names or structures. Perhaps they had to work a little harder than the tenth-year students, but they could do it. They began, however, to show definite signs of weakness when we began to deal with more theoretical matters such as genetics, eugenics, and evolution. In theoretical concepts they could not hold a candle to the tenth-year students. Their discussions of these things revealed immediately that they were far less mature than necessary to appreciate and understand what was beneath the surface in these subjects.

Conclusion

So, having been an innocent and unwitting pioneer in the move to push biology into the ninth year, I am forced to conclude that it is not such a good idea. I do not think that high school freshmen are mature enough to study biology—*at least not the biology we teach today in New York City.*

Oh yes, I could write a course of study for ninth-year biology. But there would be so much that I would have to leave out! I remember very distinctly the days before general science became a constant. We used to teach two years of biology—elementary biology in the ninth year and advanced biology in the tenth year. Our elementary biology was a very interesting and popular course. But what a difference from the advanced course. There were few theoretical concepts in the elementary course, because it was assumed, and rightly so, that these students were not yet ready for high level concepts. All of these were reserved for the advanced biology course.

Should we today go back to the old elementary type of course which is suitable for ninth-year students? I should hope not. I would oppose this move with all the power at my command. I conceive of such a move as a retrogressive step of the worst kind. Certainly it is not for the greatest benefit of our science-minded students. I cannot conceive of a student with a well-rounded science education who has never learned a little about how he inherits traits and passes them on to his children. Nor can I picture a well educated person who does not have some understanding of the concept of evolution, or of the unity of all races of mankind. And this would be the inevitable outcome of a return to ninth-year biology of the kind we once taught. Ninth-year students are just not ripe for these concepts.

And just one parting remark—for those who are pushing the idea. Remember, just as tenth-year biology is not suitable for ninth-year students, so eleventh-year chemistry or physics is not suitable for tenth-year students. That one year of difference in experience will still be there. The result will be that the physical sciences will also have to omit many of the important theoretical concepts if they are to be successful with tenth-year students. And will this achieve the aim which is in theory the motive behind the move towards demoting biology?

Biology Achievements in Grades 9 and 10

GEORGE E. MATHES

Principal, Morey Junior High School, Denver, Colorado

and SAM BLANC

Coordinator of Instruction, Denver Public Schools, Colorado

(MARCH 1960)

This report and the article following by L. H. Heidgerd represent two studies which yield conflicting evidence on the question: At what grade level should a course in general biology be placed?

ONE OF THE unsettled questions in science education has been the grade placement of general biology. Traditionally a senior high school course, some authorities have indicated that biology could be taught in junior high school to selected ninth-grade pupils. In order to validate this hypothesis, the Denver Public Schools offered a course in biology to selected pupils in grade nine in five junior high schools during the school year 1958-1959, and compared results with unselected high school pupils in grades ten, eleven, and twelve and with an equated group of tenth-grade pupils. This report is therefore a summary of the pilot study.

Purpose of the Study

The purpose of the study was to compare the achievement of selected ninth-grade students with the achievement of high school students in general biology, as measured by a test of general biology developed by Denver science teachers.

Pursuing science avidly, ninth-grade girl student ranks high in ability and performance.

ATLANTA PUBLIC SCHOOLS

Development of the Measuring Instrument

The test was developed by a committee of junior and senior high school biology teachers. Content was based on the approved course of study in use in the Denver Public Schools. The questions sampled the student's understanding of factual information and certain laboratory experiences from each of the units included in general biology. The test consisted of two parts and took two class periods to administer. Part I consisted of ninety multiple-choice questions designed to measure the student's ability to recall certain facts, principles, and concepts. Part II consisted of forty multiple-choice questions designed to measure the student's ability to generalize from certain laboratory experiments. The test was administered to all second semester biology pupils in the junior and senior high schools near the end of the school year. The total number of pupils taking the test by grade level and sex is given in Table I.

TABLE I

Number of Pupils Participating in the Study by Grade Level and Sex

Grade Level	*Boys*	*Girls*	*Total*
Junior High School, Grade 9	143	56	199
Senior High School, Grade 10	415	393	808
Senior High School, Grade 11 and 12	159	281	440
Total	717	730	1,447

Schools and Pupils Involved in the Study

The study involved most of the students taking biology in junior and senior high schools during the second semester of the 1958-1959 school year. The senior high school pupils in the study were those who were enrolled in the standard biology course. The junior high school pupils were those who were completing the same course in grade nine. These ninth-grade biology students were selected on the basis of their interest in science and in science-related careers, their ability as measured by a standardized intelligence test, their grades in academic subjects, and the recommendations of their science and counseling teachers. The high ability of the ninth-grade group can be seen from the distribution of scores on the Otis Test of Mental Ability. Table II reports the range and interquartile scores.

TABLE II

Range and Measures of Central Tendency for Pupils Taking Biology in Grade Nine as Measured by The Otis IQ Test (199 Pupils)

	Boys	*Girls*	*Total Group*
Q_3	127.0	121.0	124.0
Median	119.0	115.3	118.5
Q_1	112.4	112.0	112.3
Range	101-142	101-133	101-142

Comparison of Selected Ninth Grade Pupils with Unselected High School Pupils

Since the test was given to practically all ninth-grade and high school pupils taking biology, it was possible to compare scores of the two groups. A comparison between the measures of central tendency and range indicated that the ninth-grade pupils did substantially better than the high school pupils. This was to be expected since ability was one of the factors in selection of the ninth-grade pupils. Table III compares the measures of central tendency and gives the range of the two groups.

TABLE III

A Comparison Between Selected Ninth Grade Pupils and High School Pupils on Parts I and II of the Test (Perfect Score = 140)

	Ninth Grade	*High School*
Q_3	106.0	94.0
Median	97.5	82.5
Q_1	87.5	70.0
Range	59-128	25-125

Comparison between Equated Ninth and Tenth Grade Pupils on Parts I and II of the Test

Matched Groups

An attempt was made to equate the ninth-grade pupils with an equal number of tenth-grade pupils and compare the scores made on the test. This was accomplished using all of the 199 ninth-grade group and selecting an equal number of boys and girls with almost identical IQs' from the group of tenth-grade test results. The ninth-grade Otis IQ score was used for both groups. The range and measure of central tendency for the two groups are given in Table IV.

TABLE IV

Range and Measures of Central Tendency between Ninth and Tenth Grade Pupils Matched on the Basis of Sex and Scores on The Otis Test of Mental Ability (143 Boys – 56 Girls)

	Ninth Grade		*Tenth Grade*	
	Boys	*Girls*	*Boys*	*Girls*
Q_3	127.0	121.0	125.3	121.0
Median	119.0	115.3	119.6	115.3
Q_1	112.4	112.0	112.4	112.0
Range	101-142	101-133	101-138	101-133

The two groups are so similar that for all practical purposes they may be said to have equal ability.

Part I of the Test

Studies of the two matched groups were made for boys and girls on Parts I and II of the test. One hundred forty-three boys and fifty-six girls participated in this phase of the study at both ninth- and tenth-grade levels. Part I of the test consisted of ninety questions. In general, boys did better than girls in both the ninth and tenth grade. The interquartile range for the ninth-grade group was 56.3 to 70.8 and for the tenth-grade group, 52.7 to 67.2. The range of scores is almost the same but the top scores for the ninth-grade group are higher than for the tenth-grade group. Likewise, the low scores in the tenth-grade group are below those for the ninth-grade group. This would indicate that the ninth graders, in general, did better on Part I of the test than did their matched tenth-grade counterparts. Data are given in Table V.

TABLE V

A Comparison of Measures of Central Tendency and Range for Matched Groups of Ninth and Tenth Graders on Part I of the Test (143 Boys – 56 Girls. Perfect Score – 90)

	Ninth Grade			*Tenth Grade*		
	Boys	*Girls*	*Total*	*Boys*	*Girls*	*Total*
Q_3	71.7	66.0	70.8	69.7	65.4	67.2
Median	66.5	60.5	64.4	61.9	56.5	61.2
Q_1	58.8	58.3	56.3	56.4	49.5	52.7
Range		42–89			41–85	

Part II of the Test

Part II of the test consisted of forty questions. Again boys did slightly better than girls in both groups. The range of scores in the ninth-grade group was from 17 to 40 correct, and for the tenth-grade group from 19 to 40 correct. The median score for grade nine was 35.1 and grade ten 33.2. This may indicate that again ninth-grade pupils did slightly better on Part II of the test than tenth-grade pupils. The high scores made by both groups on Part II of the test may indicate that both groups learned how to generalize and apply the principles of biology equally well. Data for range and measures of central tendency for Part II of the test are given in Table VI.

TABLE VI

A Comparison of Measures of Central Tendency and Range for Matched Groups of Ninth and Tenth Graders on Part II of the Test (143 Boys – 56 Girls. Perfect Score – 50)

	Ninth Grade			*Tenth Grade*		
	Boys	*Girls*	*Total*	*Boys*	*Girls*	*Total*
Q_3	37.3	35.6	36.1	37.1	34.9	35.7
Median	35.2	32.9	35.1	33.3	33.1	33.2
Q_1	31.9	29.8	31.2	31.7	29.3	29.8
Range		17–40			19–40	

Summary

On the basis of a study of the scores on the total test for the matched groups of ninth- and tenth-grade students, it would seem that selected ninth-grade pupils can achieve as well, and in some instances better, than tenth-grade pupils of comparable ability in general biology. In Part I of the test the differences among the three measures of central tendency used are probably large enough to have some statistical significance. In Part II the large number of scores may indicate that the test was not difficult enough for the higher ability pupils. Consequently, the difference between the two groups was not so great and may not be a significant difference.

Conclusions

This pilot study was established to test the assumption that selected ninth-grade students could do as well as tenth-grade students in a course in general biology. The data reported here point out clearly that the group of ninth graders selected on the basis of ability, interest in science, and teachers' recommendations did considerably better than unselected high school students. When compared with a group of tenth-grade students selected to match the ability of the ninth grade, ninth-grade students did slightly better than the tenth-grade group. Boys did slightly better than girls in both groups.

More on Ninth Grade Biology

LLOYD H. HEIDGERD

Associate in Test Development, Educational Testing Service, Princeton, New Jersey

(MARCH 1960)

SHOULD REQUIRED ninth-grade general science be eliminated and replaced with required ninth-grade biology? This is a question which is receiving some considerable attention. A number of reasons have been advanced for considering this move. Among them are: (1) Ninth-grade general science is often repetitious of upper elementary or early junior high school science; (2) Radio, television, and wide distribution of popular science books and magazines have increased the general science knowledge of most youngsters; and consequently (3) Many youngsters are bored by the customary ninth-grade general science course; and (4) These are not times to waste effort in science education.

Arguing positively, it has been held that high school students would obtain a higher average level of science knowledge if ninth-grade biology were introduced, particularly if it were followed by a tenth-grade physical science course. A two-year general science sequence would be established without the boring repetitions and consequent ineffectiveness of seventh- and eighth-grade general science in ninth-grade general science and the unnecessary duplication of the biology unit of ninth-grade general science in tenth-grade biology. This argument, of course, assumes that the present practice of the majority of students taking two years of science continues. According to government figures approximately 75 per cent of the U. S. tenth-grade population is enrolled in biology (1). Assuming now that tenth-grade physical science is offered, it can further be reasoned that weak science students would be eliminated from taking physics or chemistry or better prepared for those courses by their experience in tenth-grade physical science. In effect, standards in chemistry and physics could be raised. Moreover, well-qualified students could be excused from the physical science course if they included chemistry and physics in their course plans. This would allow room for an advanced science or a course of interest in another subject matter area.

The study which is summarized in the following paragraphs was an attempt to get data on some of these arguments. The approach used made practical an investigation possessing some notable differences from previous studies of the same or similar curriculum changes. Among these differences were: (1) More teachers were involved—four biology, three physical science, and three physics teachers; (2) The achievement of a relatively large number of students, over 425 in biology alone, was evaluated; and (3) Total school populations were included.

Suitable measuring instruments and standards based on the common, contemporary high school science curriculum were provided when the World Book Company made available the complete standardizing samples for the general science, biology, and physics tests in its *Education* and *Adjustment* series (2). From the company's data the mean scores obtained by the students of each school used in the standardizing samples of the achievement tests were computed. These mean achievement scores were then adjusted to a common IQ* and empirical distributions of school achievement means constructed. These three distributions, one for each of the subject matter tests, were the standards against which the schools offering ninth-grade biology were compared.

Two schools had been located which were offering ninth-grade biology and tenth-grade physical science. The method of school selection introduced a bias since schools pioneering in curriculum change would be likely to have a better-than-average faculty and administration, but such, or an equivalent, bias was unavoidable. Students in the two schools were given the appropriate achievement tests at the end of the school year, mean scores were computed for various groups of students within each school, and these means adjusted to the common IQ to which the comparison distributions of school means had been adjusted.

Now to move to the testing of some of the values which it was thought would be fostered by the change in curriculum. Underlying the advocacy of ninth-grade biology is the assumption that ninth graders will do as well in biology as tenth graders.

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* Regression coefficients of achievement against IQ were computed, and the mean achievement scores all adjusted to a single IQ according to the slopes of the regression lines.

The first problem was to test this assumption. This was done by using the standardizing sample of the *Nelson Biology Test* modified to include tenth-grade students only.

The adjusted ninth-grade biology mean for the 303 students in one school, which we will call School A, ranked 51 from the top among the 60 schools in the standardized distribution; the 124 students in the second school, which we shall call School B, ranked 57 from the top. When the students of School A and School B were grouped according to their teachers, the results shown in Table I were obtained. The students in School B could not be divided because only one teacher was involved. As can be seen, the classes of three of the four teachers ranked 55 or further from the top among the 60 school means.

TABLE I

Ranks of Student Groups According to Teachers on the *Nelson Biology Test*

Teacher	1	2	3	4*
Rank	55/60	42/60	57/60	57/60
Number of Students	115	101	87	124

* Taught all students in School B

To clarify the meaning of this low ranking, Table II shows how many standard score points the mean scores lay below what would be expected according to the mean intelligence quotients of the groups, assuming the schools were average schools.

TABLE II

Differences between Expected Mean Scores and Obtained Mean Scores on the *Nelson Biology Test*

Teacher	1	2	3	4*
Obtained Mean Score	111	113	111	106
Expected Mean Score	116	116	117	113
Difference	–5	–3	–6	–7
Number of Students	115	101	87	124

* All students in School B

It should be pointed out that the expected mean of all students on the test is 104 and that the higher expected means here indicate that the students used for this research had high average ability.

Using the concept of the standard error of estimate based on the regression of achievement upon IQ, these groupings of students were 1.7, .97, 1.7, and 2 standard errors of estimate below prediction. Thus three of the four groupings of students turned out to have obtained mean achievement scores which were lower than would be expected of 95 per cent of similar groups of students, and all were below prediction. These data did not produce statistically significant differences since the extensive variability of the large control sample did not permit such a determination.

Assuming then that the most determinative data available under the present state of knowledge indicates that achievement in biology is less at the ninth-grade level than at the tenth-grade level, is the difference large enough and of such a nature as to be educationally important? The answer to this question is largely a judgmental matter. Though such information as is presented in Table II is helpful, the answer would also depend on how well other educational objectives had been reached. It is possible that the loss in achievement might be compensated for by other educational gains.

I shall now turn to an examination of two such possible gains which were assumed to have been obtained from introducing ninth-grade biology in the two schools involved in this investigation. The hypothesis was made that ninth-grade biology and tenth-grade physical science would lead to a better knowledge of general science since the students who completed both courses would have had a two-year course in general science. This hypothesis was tested with the *Read General Science Test* at the end of an elective tenth-grade physical science course. The results are shown in Table III.

TABLE III

Ranks of Mean Scores of Groups of Students after Ninth Grade Biology and Tenth Grade Physical Science Using the *Read General Science Test*

Teacher	1	2	3*
Adjusted Rank	24/57	28/57	5/57
Number of Students	98	21	31

* Students in School B

The results given in this table do not support the hypothesis except perhaps in the case of Teacher 3 where one must keep in mind that this is an instance where the teacher factor probably entered the picture. The students of this teacher might have done just as well had they just finished the ninth-grade general science course with him. In fact, the students of teachers in five schools out of the 57 in the test standardization group did perform just as well or better.

The hypothesis that high school physics students would do better in schools offering ninth-grade biology and tenth-grade physical science was tested in the same manner as were the other two hypotheses except that the *Dunning Physics Test* was the instrument. Here the results were encouraging as is shown in Table IV.

TABLE IV

Ranks of Mean Scores of Groups of Students after a Physics Course in the Eleventh or Twelfth Grade Using the *Dunning Physics Test*

Teacher	1	2	3*
Adjusted Rank	38/42	1/42	7/42
Number of Students	25	26	70

* Students in School B

Teacher 1 had a low ability class most of the members of which probably should not have taken physics, or if they had done so, they should not have been rated on the basis of the test used. If one accepts this exception and looks upon the results as encouraging, it must be kept in mind that again they are not statistically conclusive. They do, however, point out that the ninth-grade biology, tenth-grade physical science sequence is not inimical to high achievement classes in physics.

On the whole the trends of results were negative toward the plan of ninth-grade biology and tenth-grade physical science. And, two sources in the literature reinforce this picture (3,4).

The limitations of the findings of this study illustrate the difficulty of evaluating a going-school situation objectively. One obvious limitation was the use of a single criterion test for each course. A statistical difficulty revolved around the problem that the many factors influencing test scores caused such a wide variability that the effects of the curriculum change alone could not be detected at a level which would be statistically significant.

In conclusion, it would seem that the change to ninth-grade biology and tenth-grade physical science should only be made if it is expected that there will be some loss in biology achievement and that other gains will make the change worthwhile. Since local factors, such as teacher interest, may greatly affect the success of the new program, it should be evaluated in terms of local objectives after giving it enough time for fair trial. Inherent in the concept here presented is that the findings might indicate a return to the old program or a shift to another new program.

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Physical Science Today — A Symposium

(FEBRUARY 1951)

OUR experiences of recent months have led to the conclusion that brief accounts of current efforts directed toward modifying the physical science portion of the curriculum, if reported through the pages of *The Science Teacher,* would be helpful to many teachers throughout the nation. Hardly a week goes by without our receiving an inquiry for "a course of study in physical science," or "the name of a teacher or school having a successful course," or "what is the trend with respect to substitute courses for conventional chemistry and physics?" Conversations with teachers during our field trips and our attendance at various conferences and meetings reveal deep interest in these questions and much concern, some on the "negative" side, with the proposed solutions. At the recent meeting of the Physics Section of the Central Association of Science and Mathematics Teachers, about 50 of the group remained more than half an hour beyond scheduled closing time to continue a discussion of physical science and the curriculum.

Actually, of course, the whole idea is neither new nor recent; "science fusion," "generalized physical science," "physics and chemistry A and B," and so on, have been in the air for at least 20 years. During this time a considerable body of related literature has accumulated, and it is our regret that space limitations preclude giving a bibliography to accompany this symposium. Meanwhile, the movement toward "general education" science has gained much momentum at the college level—perhaps more than at the high school level. However, the recent U. S. Office of Education report, *The Teaching of Science in Public Schools* (pp. 22–23), lists by title 11 different groups of alternate courses offered, apparently, in addition to, or in lieu of, the usual general science, biology, chemistry, and physics; further, the report indicates that about 19 per cent of the high schools offer one or more such courses. More than half of the courses reported fall into the physical science area.

And so we come to our present symposium, in which nine courses scattered all over the country are reported. The accounts and course outlines that follow have been arranged so as to approximate a continuous and developmental story. Confident that their contributions will be appreciated, we express apologies to the participants in this symposium for the editorial reductions in many of their manuscripts. Space limitations and the avoidance of duplication have been the compelling reasons.

Admittedly the nine courses in this symposium represent a selected sample, perhaps even biased; but the purpose is to report promising and successful practices—not to delve into the question on a research basis. Whether the effort has been successful, and whether we go farther with this inquiry, is for *you* to judge.

Mr. O. A. Nelson of Wilson High School, St. Paul, has developed a course emphasizing "physics in daily use." Here is what he has to say about it.

"If pupils are to receive the greatest benefit from the time spent in the classroom, the material taught must be on the ability level and interest level of the individuals. However, with 25 to 40 pupils in a class, each having different interests and varied abilities, how is it possible to teach in such a way that each pupil can profit to his full capacity? This paper will deal with one method that has proved successful, for the writer, in teaching physics.

"Our first attempt was made by dividing the pupils into groups according to their abilities and interests. This arrangement led to some improvement, but there were also some serious weaknesses. A heterogeneous grouping was used the next year, and this was found to be much more satisfactory. A number of procedures were used to meet individual differences in such a grouping.

"We felt that in any science class each member should do individual work in the form of projects; also that, as far as possible, class time should be given for this work. In most cases this may be accomplished in much the same way as is done when we carry on the usual laboratory experiments. After the project has been completed, the pupils should be given an opportunity to discuss their findings before the class. A science-minded pupil should give a much better report than one who is lacking in science ability, even though they are on a par in general ability. Also, a science-minded pupil of high general ability should give a better report than a science-minded pupil of low general ability, but, if their work is comparable to their ability, they should receive the same grade. If no counselling service is available, each teacher must give some tests and check other sources of information to obtain enough data to place each pupil in the proper ability classification.

"After each pupil has been placed in the proper classification, the instructor must exercise good judgment in permitting the pupil to select projects or topics for experiments and reports that are near his ability range. Care must also be exercised so pupils of high ability do not select projects that are too easy for them.

"To keep and develop interest among a large number of pupils, the subject matter taught in physics cannot be the traditional, technical, college preparatory material found in the average text. The same laws and principles must be taught, but the approach must be through experiences on the age level of the average physics pupil and with materials in which he is interested. The writer found that most high school pupils were interested in learning more about the machines used in their homes and in business places. As each machine was examined and studied, one or more of the laws or principles of physics was discussed and mastered. Note specifically that the machine was studied first and not the law or principle. Not all the laws and principles used in one machine would necessarily be discussed in connection with that machine. If this should be done, the pupils might be kept at one topic too long, and interest would decrease rather than increase. By using a checklist, everything found in the conventional physics text can be discussed in an interesting and simple way during the school year.

"Pupils of exceptional ability should be given special consideration in any class. The Westinghouse Science Talent Search offers special inducement and interest as do other similar offers of scholarships. Those pupils were permitted to work in the laboratory on their special projects during class discussion when the instructor felt that the lesson for the day had already been mastered by those individuals.

"Readers of this article will ask certain questions, and the writer will try to answer three. (1) In a course of this nature, does the pupil learn as much good sound physics as in the traditional course? (2) After having taken the above-described course, how does the pupil get along when taking college physics? (3) What evidence is there that the above-mentioned approach of physics develops more interest in the course?

"Question 1: The writer has used the above approach in teaching physics for about 12 years. Seven times standardized tests have been used as the final examinations. About five per cent got scores falling in the lower decile on the standard tests. About six per cent received scores in the upper decile. About 50 per cent of the writers' pupils received scores that were in the 35th to 65th percentiles on the standardized tests.

"Question 2: Only a small number (28) of pupils taking physics at college were checked in their progress. In no case did any one receive a lower grade than that given in their high school work. None were below the 40 per cent rank in college grades.

"Question 3: The writer has taught physics for 24 years. The last year he used the "technical approach," 34 pupils out of a graduating class of 328 had elected physics. Eleven years later in the same school 411 pupils out of a graduating class of 456 had elected physics. If numbers are a criterion, the results speak for themselves."

At Arlington Heights Township High School, Arlington Heights, Illinois, Mr. Nelson Lowry, head of the science department, and his colleagues, Mr. John Schaff, and Mr. Melvin Kulicke, have a modified science program now in its third year.

"Biology is now required for all our ninth-grade students and may be followed by a physical science course in the tenth grade. This two-year program is followed by physics, chemistry, or advanced biology for those with interests or needs for advanced work.

"It takes time to reorganize and set up a new science curriculum. Our planning began in the fall of 1946. For two years we worked on many possible changes. The science department and administration were in agreement that general science was no longer meeting the needs of our students. The grade schools were doing what the high school had been doing in the general science course. In the fall of 1948 we dropped general science and required biology as a ninth-grade subject. We no longer are repeating the work of the grade schools. We have recognized their work, and since making our changes have found the work of elementary schools greatly improved.

"Our physical science course is now in its second year. The course is planned to be of practical value to the student as well as an introduction to the specialized courses. Student interest is increasing in this course and in others. Chemistry enrollment has increased, and we expect the same trend in physics next year. The work in chemistry has been accelerated over previous years. The students having had physical science appear to have an advantage in chemistry over those not taking the course.

"We have experienced no difficulty in changing the traditional curriculum. The science department planned the program with all the basic reasons for the changes and then outlined the proposed physsical science course before presenting the program to the administration for suggestions. The school was fortunate in having a staff of well-trained science teachers interested in the students and willing to take on the additional work involved in changing the course of study.

"The state department has recognized the changes as desirable. Colleges and universities are giving a unit of entrance credit for the physical science course."

ARLINGTON HEIGHTS COURSE OUTLINE

Introduction—2 weeks
  (1) Nature of physical science
  (2) Laboratory procedures
  (3) Measurements
Solar System—3 weeks
States of Matter—2 weeks
Energy—2 weeks
Physics—15 weeks
  (1) Forces
  (2) Force and motion
  (3) Work, energy, and power
  (4) Sound
  (5) Light
  (6) Electricity
Chemistry—12 weeks
  (1) Chemical change, oxygen, hydrogen, combustion
  (2) Nature of chemical process
  (3) Solutions
  (4) Nonmetals and their compounds
  (5) Organic chemistry
  (6) Useful metals

"Forty experiments are included which may be done as (a) teacher demonstrations, (b) student demonstrations, (c) group experiments (two–six students), or (d) individual experiments."

From the "deep South" comes this contribution from Mr. S. A. Brasfield, director of the Division of Instruction, State Department of Education, Jackson, Mississippi.

"The national trend in secondary school curriculum development is definitely toward setting up programs that are practical and tend to meet the needs of all youngsters in our secondary schools and the youngsters that should be in secondary schools that are now classed as drop-outs. The national movements directed toward 'Education and Life Adjustment,' 'The 1950 Edition of the Evaluative Criteria,' and 'The Ten Imperative Needs of Secondary School Youth' are all based on the idea that all students that go through our secondary schools should have certain experiences and training regardless of what they plan to do after leaving the secondary schools. It usually boils itself down to saying that all secondary schools should set up a Common Learning Program, which embodies from 50 to 60 per cent of the 16 units usually required for high school graduation. It is our belief that in any Common Learning Program there certainly should be an opportunity for the youngster to spend at least one year studying the biological sciences and a minimum of one year on the physical sciences.

"Many of our schools in the South require these two courses as a part of the Common Learning Program in their high schools. A course in general physical science definitely has a place in the Common Learning Program on the 11th and 12th-grade level. This does not mean that every student should take a special course in general physical science. Some students probably should take physics, others should probably take chemistry, and many students may need both of these courses; but, certainly every youngster should have at least one year of a physical science.

"In Mississippi secondary schools we are recommending general physical science for both our large and small high schools. If the school is so small that only one course can be offered in the broad field of physical science, we think the general course would come nearer meeting the needs of all youngsters on the 11th and 12th-grade level than the specific course in either physics or chemistry. In the medium size and larger high schools of the state we definitely think there is a place for a course in general physical science for those students that do not take physics or chemistry. However, we feel that a very high percentage of our students in the 11th and 12th grades in all our high schools need a general course in physical science more than they need a technical course in physics or chemistry.

"We believe the course should include laboratory work. We certainly think there is a place for visual-aids and field trips. We would definitely encourage pupil-teacher planning, not so much in the sense of what units will be studied, but how the units will be studied."

Is New England as conservative as sometimes pictured? Mr. R. E. Keirstead, head of the science department, Bulkeley, High School, Hartford, reports on his experimental physical science course.

"A survey of Bulkeley High School juniors and seniors showed that a considerable percentage of non-college preparatory pupils were being graduated without taking any science courses during the last two years of high school. In view of the importance of science in modern life it was felt that most pupils should take at least one course in science during the final two years of high school in order to have the intelligent appreciation of the methods, potentialities, and limitations of science so necessary for a citizen of today. Accordingly, a single experimental class in physical science was set up in September, 1949, with the express purpose of trying to find the answers to two questions: (1) What subject matter from the area of physical science is of real interest and significance to pupils at the 12th-grade level and who are not going to college? (2) What methods of teaching are best suited in presenting this subject matter?

"At the first meeting of the class the pupils were informed that the aim of the course was to provide them with a concept of the role science is playing in modern life and with information and points of view of immediate usefulness in understanding science as it is met in newspapers and magazines, on radio and television, and in the materials and gadgets of daily life. No textbook was adopted as it seemed likely that this might prevent the development of the course along the lines of interest of the pupils. Excellent library facilities in our school made it possible to carry on the course without serious inconvenience from lack of a text. The adoption of pupil planning as a technique proved to be a happy one but did not make the role of the instructor any less important. Rather, his task was more difficult than in a formal course for he had to show considerable ingenuity in guiding discussions and in directing the learning process toward desirable ends. Many members of the class had had very poor academic records yet, when given an opportunity for active participation, presented many intriguing and surprisingly searching queries.

"The course was organized around large topics or units. Each such unit was chosen by vote of the class after a free and often exhaustive discussion. A study guide consisting of questions to be answered was then prepared in mimeographed form by the instructor. Demonstrations, motion pictures, and other visual aids were used as widely as possible. No individual laboratory work was done. The treatment of scientific principles was almost entirely qualitative. Very little written homework was assigned. Quizzes were held frequently with full period examinations at the end of each marking period.

"The major units of the course were: (1) Providing a Supply of Water, (2) Atomic Energy, (3) Mineral Resources of the World, (4) Metals of Importance to Modern Life, (5) Building Materials, (6) Fuels, (7) Synthetic Substances, (8) The Automobile, (9) Communication, especially Radio and Television, (10) Photography, (11) Weather and Its Forecasting, and (12) Astronomy.

"One might suspect that the method used in organizing the course would result in a hodge-podge of isolated and unrelated topics, lacking the unity and coherence of a formally-planned course. This did not prove to be the case. The great concepts of science so permeate its whole body that they furnish an excellent framework about which any subject matter can be grouped. The atomic theory, the kinetic molecular theory, the electron theory, the principle of conservation of matter and energy, the concept of radiant energy, and other similar ideas provided a satisfactory unity.

"The guidance staff of the school evaluated the course through personal interviews with pupils. It was the unanimous conclusion of the guidance counsellors that the pupils had profited greatly from their experience in the course. Pupils' anonymous statements concerning their reactions to the course proved valuable not only in showing the course to be of value but also in providing suggestions for improvement.

"From our experience to date it seems clear that many high school pupils who heretofore have avoided the traditional high school science can profit markedly from a generalized physical science course built around aspects of science which are of real significance to them in their daily living. Furthermore, it seems entirely possible to develop a real appreciation of the part that science plays in the world of today, even in the less able pupils. We believe that more regular and careful daily preparation would result from the use of a textbook. However, if the advantages gained from pupil participation in planning the course are to be retained, the textbook must be used as a source book rather than an outline to be followed rigorously. Possibly the organization of texts on physical science should be along different lines from those now available."

The Baltimore County, Maryland, public schools offer two years of consumer science for senior high school pupils who do not need or want conventional courses in chemistry, physics, and in some cases, biology. Miss Helen Hale, supervisor of secondary schools, reports on this program.

"The genesis of our present consumer science program may be traced to the late 1930's when several Baltimore County teachers began to experiment with a modified course in senior high school science. The experiences of these teachers and their classes produced a tentative course of study in senior science which was used for seven years. When later curriculum committees sought to establish a set of specific purposes for a somewhat broader program of consumer science, they did so on the basis of the findings of the senior science teachers, as well as on such other factors as (1) the meager results of research in the area of modified science, (2) the principles for secondary education set up at a 1945 state workshop and set forth in a series of bulletins called *Maryland Looks Ahead in Education,* and (3) the philosophy and major purposes for senior high school science which had been developed in a 1948 county workshop.

"Committees of teachers working during the year and in summer workshops have prepared tentative courses of study which include six units for each year of consumer science. The units themselves are somewhat of a resource nature so that each group of pupils may develop their study along lines best suited to their interests and needs and in the light of their past educational experiences. For example, the unit dealing with the human body, which was placed in the course as essential for pupils who have not had biology, is frequently omitted for at least part of the class, inasmuch as many pupils do not decide to elect consumer science until after they have already had a course in biology.

"Because there are no stringent subject-matter requirements, emphasis can be placed on rich and functional learning experiences rather than on ground-to-be-covered. Pupils are given many opportunities to learn directly, even though this type of learning is time-consuming. For example, one consumer science II class recently decided to spend a rather large block of time on the unit, *Building and Equipping the Home.* In their study the pupils viewed six sound films and seven filmstrips, studied 26 different government and commercial pamphlets, used several dozen reference books and read numerous magazine and newspaper articles, took six class-wide field trips and made four group visits, built seven large models, made eight collections, prepared some 20 posters, performed eight experiments (several of a controlled nature), engaged in many informal discussions and two panel discussions, arranged six bulletin boards and three exhibit-case displays, prepared a photographic summary of their activities, made a set of slides to summarize the unit learnings, and wrote and recorded a script to accompany the slides. In this class, as in most consumer science work, much of the learning was done by groups formed on the basis of common interests.

"The laboratory work in consumer science is largely pupil demonstration, and no special laboratory period is included in the schedule. The classes meet for five 50-minute periods. However, school administrators have been cooperative in arranging temporary schedule adjustments which permit community study and other types of field work.

"A variety of reference books is supplied for classes in consumer science with material available on several reading levels. No textbook now on the market seems to be especially well-suited to our consumer science program.

"No study has been made of the success of consumer science or of the effect of this program on the achievement of pupils in the traditional senior high school science courses. Informal analysis shows, as one might expect, that consumer science is successful in some schools and not in others. In most instances the teacher seems to be the factor which determines the popularity of the course in terms of enrollment and the enthusiasm and satisfaction of the pupils once they are enrolled. The flexibility and possibilities within consumer science motivate some teachers to exceptional effort and subsequent success; the same conditions merely overwhelm other teachers.

"The major unsolved problem in consumer science is the in-service training of teachers in order that they may accept and implement the philosophy and objectives of the course. Other difficulties concern scheduling to permit more flexibility, the need for a greater variety of teaching materials, and the task of selling the program to parents."

CONSUMER SCIENCE I

(1) Chemistry for Our Daily Needs
(2) Nuclear Energy: Its Use and Control
(3) Using Water Wisely
(4) The Human Body
(5) Man and the Universe
(6) Resources and Industries of Baltimore County

CONSUMER SCIENCE II

(1) Machines in Modern Life
(2) Electricity at Work Today
(3) Building and Equipping the Home
(4) Modern Medical Science
(5) Biological and Mineral Resources
(6) Research and Testing Laboratories

Now let us see how the general physical science course is handled in the Ann Arbor High School, Mahlon H. Buell, head of the science department, reporting.

"General physical science for college preparatory students is so new in the Ann Arbor High School that the content and methods used are very definitely in the experimental stages. Its purpose is to provide an integrated course embracing some of the fundamental principles of chemistry, geology, astronomy, meteorology, and physics. It is elective for juniors and seniors who wish a laboratory physical science course. Entrance officials of the University of Michigan have agreed to accept it as a substitute for one unit of physics or chemistry when offered for entrance credit.

"College-bound juniors and seniors definitely feel a need for an understanding of their physical world and environment. They want to know the facts about the universe, from the remote and gigantic galaxies to the tiny atomic nucleii. They are hungry for knowledge and are anxious to fit all new information into a philosophy of life that they can accept for themselves. This makes it possible to organize a physical science course around such broad physical principles as the law of gravitation, the conservation of matter and energy, and the molecular and atomic structure of matter.

"The problem of finding a suitable textbook has not yet been solved. Several of the books in this field are intended for non-college preparatory groups; others definitely segregate the sciences into sections on physics, chemistry, astronomy, or geology. The latter are difficult to use in a course in which one of the aims is to integrate the subject matter into a unified whole. The textbook used in Ann Arbor, *The Study of the Physical World* by Chernois, Parsons, and Ronneberg (Houghton Mifflin Co.), certainly overcomes these objections but is too difficult for high school students; in fact, it is a college textbook. It is hoped that some of the forthcoming new books and revisions of present texts will be written for college preparatory students.

"The class meets for a double laboratory period twice a week. Among the more unusual experiments, exercises, and trips attempted are the following: a globe study including latitude, longitude, and time; the use of a slide rule; a study of weather maps; making photographic contact prints and enlargements; assembling a one- or two-tube radio set; the study of geysers, falls, mountains, canyons, rocks, and shore lines by means of colored slides; observations of the moon and planets through a telescope; trips to the Willow Run weather station and to the University of Michigan astronomical observatory.

"As the basis for the selection of subject matter frequent reference is made to other textbooks and course outlines. Greatest reliance is placed on *Principles and Experiments for Courses of Integrated Physical Science* by Vaden Miles, Wayne University, Detroit. In this book principles and experiments are rated in descending order of importance and experiments for both demonstration and individual student work are listed for each principle.

"The outline of course units is by no means fixed and final, but in general takes the following form."

Introduction—Physical Science and Its Place in Our Lives.

(1) The earth as a whole and its closest neighbors
(2) A more detailed study of the earth
(3) Some results and effects of gravitational forces
(4) Motion, a special effect of force
(5) Energy, the agent of change
(6) The molecular nature of matter
(7) The nature of chemical change
(8) Minerals, ores, and other natural resources
(9) Electrical energy, man's great servant
(10) Light energy, carrier of information
(11) Atomic energy and radiation, both dangerous and beneficial

Next we hear from Dr. John Hogg, who describes the course he has developed at Phillips Exeter Academy, Exeter, New Hampshire.

"What is a profitable alternative to the usual courses of chemistry and physics in grades 11 and 12? In seeking an answer to this question we must first raise the perennial query, 'Why teach science at all?' If we accept the dictum that the primary goal of science teaching is to understand nature, we must set our sights so as cover a wide range. The course must be broad in its scope; it must cross the conventional barriers that are usually erected between the branches of physical science; it should correlate the branches and stress their interdependence.

How can the parts be correlated and integrated? One method is to select a unifying theme and weave the story about it. A central theme that has proved satisfactory is the topic of *combustion.* It cuts readily across the boundaries. From chemistry it meanders through heat, electricity, and into light and electronics. It wanders just as easily into metallurgy, geology, meteorology, and even into astronomy and nuclear energy.

"A course built around the combustion theme could begin with oxidation, fire, and fuels, including oil and coal. The origin of coal and oil lead naturally into some aspects of geology, and it is only a slight diversion to take up such topics as the rocks of the earth, the changing earth, the record of rocks.

"Returning to the theme, temperature and heat effects should next be considered. This should include evaporation, condensation, and the methods of heat transference. This background offers an easy approach to meteorology, and such topics as winds and air masses, fronts and storms can be studied intelligently.

"Returning again to the central theme, the decks are now clear for a discussion of the steam engine, the internal combustion engine, and the airplane. Combustion in the production of electricity is next in line, and a study of the generator and transformer leads quite naturally to electric lighting. It is now an easy hurdle to jump to reflection and refraction of light. A study of telescopes takes us into astronomy, and this in turn leads to 'combustion' in the stars and to nuclear energy.

"Once the central theme of *combustion* has been selected, there are obviously many different routes across the boundaries, depending on the whims of the teacher and the interests of the students. The outline given at the end of this article shows the route the writer has followed for a number of years.

"In our course classes meet four times a week throughout the year, each period being 50 minutes. There is no required laboratory work, but field trips are a rigid requirement. For example, we visit the local water works and see water purification on a large scale. Our geological expedition is to a rocky section of a nearby beach. Another worth-while trip is to see high-pressure steam operating turbines and the turbines operating generators; and still another is the manufacture of water gas. The management of industrial plants generously cooperate and even provide guides to explain the operations. Students take notes, and these are then expanded into an illustrated theme which must be handed in to the instructor not later than one week after the trip.

"This writer is convinced that every student should be *required* to work on a project dealing with some aspect of the course that may interest him. There is no doubt that a project is a potent educational tool. At its worst, it ensures that a student does manual work in applied science; at its best, it provides an intellectual stimulant. Usually the student shows considerable interest in his project and sometimes considerable ingenuity. The best projects should be suitably labelled and put on display. A good display introduces a little healthy competition and is an incentive to skilled workmanship."

PHYSICAL SCIENCE AT EXETER

(1) The Nature of Common Things
(2) Earth Science
(3) Some Effects of Heat
(4) Weather
(5) The Chemistry of Fire
(6) Power from Combustion
(7) Combustion in the Production of Electricity
(8) Light
(9) Communications
(10) Some Chemical Industries
(11) The Universe

Down to Texas next for an account of the general physical science course developed by Frank C. Guffin, head of the science department in Austin High School.

"Our course is designed primarily for non-college students. However, it does carry college entrance credit as a laboratory science with the University of Texas. Periods are an hour long, and we allow at least one laboratory period per week throughout the year.

"About 1000 students per year 'track' through our high school physical science course. We attempt to evaluate the success of our plan through conferences with students, teachers, and guidance counselors. We *believe* we are making good headway toward achievement of our goals.

"One of the handicaps, we feel, is the one-hour period which, in a large school, severely limits our use of field trips, projects, community resources, and the like. Transportation for such purposes is another problem. Finally, we have a problem to keep this course from becoming a 'snap' course for students readily susceptible to avoiding work.

"We have not found any of the published textbooks completely satisfactory for our purposes. We rely heavily on one text, but two additional ones, plus other supplementary materials, are always available to students. The problem of guides for laboratory work is more troublesome than that of a text. We have had to write our own.

"The unit areas included in our course usually include most of the following."

(1) Understanding Science
(2) Water
(3) Fire and Fuels
(4) Simple Machines
(5) The Atmosphere
(6) Foods and Drugs
(7) Sound
(8) Light
(9) Building Materials
(10) Home Appliances

And now a hop all the way across the continent for a look at the modified physical science offering in the Los Angeles public schools. Reporting is Miss Archie J. MacLean, supervisor, science education section, curriculum division.

"We no longer have enrolled in our high schools only those students who are preparing for college, but we have enrolled today most of the youth of high school age. Consequently, our offering and methods of teaching must be adapted to this changing situation. High school science courses must not only prepare students for technical work in college but must prepare all students to live in a world of science.

"The most difficult problem is to determine what science instruction should be given to the nontechnical student in order to prepare him to live in a world of increasing technical development. The following criteria were used in setting up content for the course as presented here. Areas for study should contribute to: (1) An understanding of the basic laws of nature; (2) The solving of problems that arise in daily living such as buying goods, providing for greater convenience and comfort in the home; (3) Developing skills in critical thinking so that students will act as a result of thinking through a problem and not as a result of prejudice or tradition; and (4) A realization of the impact of science upon social life.

"The areas of study that follow are suitable and practical for use in a physical science course at the 11th or 12th-grade level for non-academic students."

Area I.	How does climate affect our way of living?
Area II.	How can we secure an adequate water supply?
Area III.	What should we know about buying clothes and household supplies?
Area IV.	What should we know about the construction of our homes?
Area V.	How can we become better users of machines in our home?
Area VI.	What means of communication have been developed for our use?
Area VII.	How can we make the best use of our transportation facilities?
Area VIII.	What do we need to know about our earth and universe?

"Suitable textbooks for physical science are limited. Much of the reading material for the course must come from supplementary materials. The teacher who has a well-stocked cupboard of printed materials from industrial firms, government publications, and current magazines is fortunate. As we all know, a wealth of useful material has been distributed through the Packet Service of the National Science Teachers Association.

"Classes in physical science should be carried on in a laboratory shop. There should be facilities for examining motors, testing household appliances, learning how to make simple household repairs, building a miniature wind tunnel, setting up and maintaining a weather bureau, and trying out various experiments to answer problems that have been raised in the discussion period. The use of equipment that is familiar to the student and that he sees frequently in stores and at home will help to make the course have direct application to everyday use. There should be a great deal of storage space for materials that teachers and students have collected, such as an old vacuum cleaner, automobile motor, student projects, etc.

"Providing the type of science course that this modern world seems to demand is not an easy task. Some teacher training institutions seem to be unaware of the need for broader basic science training for science teachers. Science teachers are usually well equipped for teaching the traditional courses, but to be a good physical science teacher requires a broad science background with emphasis on practical applications. Such a program for pre-service education is rarely found. Opportunity for student teachers to carry on practice teaching in physical science is unusual, yet it should be a part of the training of science teachers preparing in the field of the physical science.

"The breaking away from the traditional pattern of physics and chemistry for the 11th and 12th grades is a difficult problem in some school situations. The attitude on the part of some science teachers that teaching physical science is beneath their talents is a problem to administrators. If such teachers would try to develop a physical science course to its fullest possibilities, they would soon find their ingenuity challenged to its greatest extent—far greater, even, than in 'traditional' chemistry and physics courses."

From a study of these reports of experiences with nine programs of modified physical science, certain inferences and conclusions seem to be justified:

1. The high school physical sciences, at long last, are yielding to the forces which are bringing about a reconstruction of the secondary school curriculum. There is apparent a shift in emphasis from concern for subject matter itself to concern for the learner. We cannot say that the rate of change is great, but sincere efforts at modification are to be found in all sectors of the country and in all types of schools. These efforts, in the main, have taken the form of classroom experimentation rather than controlled research. Attempts have been made to evaluate results, but the methods employed have not been objective or statistical in character; their validity and resultant conclusions are open to question.
2. No clear-cut pattern for the modified course, or courses, has as yet evolved. Some courses consist of apparently unrelated blocks of subject matter, and there is little evidence, in so far as the course outlines indicate, of any integrating or unifying theme. On the other hand, there is general agreement on the desirability of such integration, and it may be assumed that the methods of instruction employed point in this direction, possibly with considerable success.
3. The proper role of the textbook in a modified course is not clear. It is generally agreed that presently available textbooks are far from satisfactory. To the extent that the course has its roots in personal and community problems, the textbook becomes less important as "the guide" to the course and becomes, simply, one more resource for teaching and learning. Possibly an entirely new concept in textbook design is needed if this long-established educational tool is to make its best contribution to modified physical science courses.
4. There is uncertainty regarding laboratory work in the modified courses. How much and what kinds of laboratory work continue to be perplexing problems. There is general agreement on the desirability of providing opportunities for individual and group activities, but how to adapt the "laboratory" of conventional chemistry and physics to more functional purposes is the problem. Again, possibly we need to devise a set of almost entirely new kinds of laboratory experiences.
5. There is general agreement on the desirability of providing for field trips and for making use of outdoor, human, and industrial and technological resources in the teaching of modified courses. However, the big problem is to find time for this type activity.
6. It appears probable that the majority of these courses have been developed by classroom teachers who have received no special time allotment for such work; the work has been done at the end of a busy day, during evenings, over weekends, and during vacation times. However, there are encouraging reports of the use of county and local workshops devoted specifically to problems inherent in developing modified courses.
7. It appears that the teacher is a "key" factor in the success of a modified course. Some teachers approach the course with enthusiasm, intrigued by its tremendous possibilities; others seem overwhelmed by the multitude of problems arising out of departure from the conventional.
8. Educators responsible for programs of science education generally agree that the teacher-education programs of many training institutions fail to produce the kind of teachers needed for the newer physical science courses. The inadequacies of pre-service education make all the greater the need for in-service education and assistance.
9. In most of the courses reported in this symposium, the "units" or "areas" as outlined are regarded more in the nature of resources or guides than as an inflexible "blueprint" for the course.
10. Many modified courses in physical science have been approved for college entrance credit by higher institutions of recognized standing.

Laboratory Work in Grades 7 and 8

RALPH S. VRANA
Science Teacher, New Lincoln School, New York City

(NOVEMBER 1961)

For the past two years I have worked out a series of laboratory sheets for the students in our school, and have placed the major emphasis on these sheets to teach general science in the seventh and eighth grades. (The two groups are taught together.) This approach has been the most effective one for me in getting the major part of the class involved in science work. While the approach is not new, the problems are of a character which might interest other teachers who would like to experiment with this method. These were the bases from which the work proceeded:

1. Each student should have enough materials and equipment so that he could work out experiments for himself (or at most, with one partner).
2. Emphasis was placed on fundamental principles, which might be illustrated with easily obtainable materials for class quantities.
3. The laboratory sheets were prepared to acquaint students with science phenomena. While the results often were interesting, they were explorations. for the student into already well-established fields; a sort of "readiness" program for major laboratory involvement in senior high courses.

The benefits from this approach could be listed as these:

1. Freedom for the teacher to help those who need it without holding back others.
2. An easily checked and reliable guide to students' progress and capacity.
3. A tapping of the student's desire to explore the surroundings for himself; this in a constructive way.

There are also certain handicaps to this approach which might be listed:

1. Accumulating materials in class-room quantities for sufficient experiments for a full-year course can be difficult and time-consuming.
2. There is not time enough for students who show more than average interest in an area to complete the assigned sheet and then to work on his own. Since working from a laboratory sheet is easier, care must be taken to see that a supplement exists.

How does one go about making up a laboratory sheet for seventh- and eighth-grade students, which will teach them some principles of science, and do so in a fifty-minute period? Let us suppose the subject is *heat*. Problems that naturally fall into general science for this age group would be:

1. The measurement of certain temperatures around us.
2. What happens to heated objects?
3. How can heat be produced?
4. What are the means by which measurement of heat is accomplished?

To pursue these problems satisfactorily with laboratory sheets, each student must have a thermometer. The variety found in the dime store (29¢) has been found satisfactory for temperatures below 120° F but is distinctly not for use in hot tap water. Once purchased, the actual dimensions and characteristics of the particular thermometer on hand dictate to a large extent what the laboratory sheet would include. Perhaps this goes against the accepted idea that one should plan science activities before purchasing materials, but there is much to be said for a reasonable amount of planning of science activities around available materials. First the general area of study is selected, in this case, *heat*. Then a search is made for available and inexpensive materials which will fit in with individual laboratory work. Once these are found, planning should include the exploration of how to use the materials.

The thermometers used in the class had a range from $-46°$ F to 120° F. Students were asked the range of the thermometer (which was *not* immediately apparent), and to record the present temperature reading they found. Reporting was done on the laboratory sheet itself, which had been duplicated for class use. Several questions were asked as to what part of the thermometer was most sensitive to temperature changes. This was determined by the student putting his finger on different parts of the thermometer tube. How cold is cold water? This was easily determined by filling a jar with tap water, and inserting the thermometer in it. Where is the warmest part of the room? This also was begun by having students standing on chairs (or tables if possible) and comparing the reading with that obtained on the floor. Sometimes the order of questions is important. If the thermometer is put in water to test its temperature, and then used to test the warmest part of the room, the reading may be in error due to water drops on the bulb.

Further work with the thermometer can easily be undertaken. The temperature of icy water in either the Centigrade or Fahrenheit reading is easily obtained. We undertook to find how much of a temperature drop could be achieved by adding salt and chopped ice to water. Throughout it all, the student is brought back to the work at hand by the laboratory sheet, which provides him with directions and where to find the materials in the laboratory. We must remember that seventh- and eighth-grade students frequently need explicit help, especially in the use of apparatus unfamiliar to them. Since their experience in a science laboratory is probably nil, this help must be continual, and in the course of the year should include considerable practice in reading thermometers, using filter paper, lighting burners, etc. In this way, the distaste that some students develop through lack of knowledge for unfamiliar materials of the high school physics or chemistry laboratory will be avoided.

Supplementary explanations for most of the questions in the laboratory sheets were not necessary. But those few questions which did bother students for one reason or another, do contribute to many difficulties. Often the student's hasty reading will be a fault, but there were a few questions basically unclear. I kept a clipboard with a black laboratory sheet on it to note the questions which confused students. When these laboratory sheets are used again, they will have fewer rough edges.

To maintain a balance, the laboratory sheets were prepared so that for each question some sort of written response is necessary. This response often may be only a "yes" or "no" but the only way to determine a correct answer is for the student to do the work. Some questions might require a sketch, or a more detailed paragraph of explanation. If the student is not asked to report what he has done, he thinks the experiment is unimportant, and is apt to evade the work entirely. Perhaps this is oversimplification, but we must realize the current trend in our living to make life easier. A laboratory sheet which does not ask for specific response may appear to the student as just another TV channel which can be turned off if not found interesting. In other words, I believe it is necessary for the student to learn that the laboratory sheet needs to be completed, not only to benefit himself, but for review or correction by the teacher. It is not heartening to see students working on laboratory sheets *only* because they wish to get the "right" answers to the teacher. However, in the best of lab sheets the student is swept away by his work and the classroom becomes an active center of investigation. It is heartening to see one's work reaching a full class of students each individually interpreting it. If there is any flaw in the lab sheet, they will soon discover it.

In our school the average class size is 25, and to handle even this many students with laboratory sheets, it is necessary that all materials for the experiment be set out, and *that there be enough of them.* When we list the requirements of the materials involved in this method of teaching, we realize that their acquisition may sometimes cause a problem. They must be inexpensive. They must be readily obtainable. They must be reasonably safe to handle. They must serve in some way to illustrate science principles. They must be simple enough for seventh- and eighth-graders to work with them independently. Those who live in a large city have some advantages in gathering materials, especially in the physical sciences. (New York City has its Canal Street where lenses, prisms, electronic parts, glassware, tools, and much government surplus materials can be had.) The Federal Government has surplus property which it sells at a fraction of cost to schools, and these items can be obtained by any school.* There are many books on the market today which provide a wealth of experiments for class use.

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* Alan Mandell. "Uses of Surplus Property Materials." *The Science Teacher*, 27:32 November 1960.

Criteria for Independent Study Projects

DONALD WYNANT HUFFMIRE

Instructor, Management Science, Monmouth College, West Long Branch, New Jersey

(MAY 1961)

INDEPENDENT STUDY is the pursuit of a special topic or project by the individual under the guidance of the teacher or other science educator as a part of the regular science course. It is not usually done in school. A project is a problem upon which a student works. It may require an empirical investigation. It may require doing an experiment, making a chart, making a model to illustrate a scientific principle, writing a report on a scientific article or book, or writing a report on a science topic of interest.

Science. The major project of the student should be in a scientific area. Science has many definitions. The authorities generally agree that science should be concerned with: (1) searching for knowledge or truth, (2) reflective, creative thinking about problems, (3) forming generalities from observations, empirically gathered evidence, and experiments, (4) using the inductive and deductive reasoning processes, (5) leading one to new concepts, experiments, and problems from each project solved. It is also concerned with methods of attack on problems, tactics and strategy by which problem solving and concept formation are carried out.

Educational and scientific objectives. Projects should help the teacher achieve the main objectives of science teaching. From the literature, it appears that educational objectives of science can be classified under these main headings:

1. To teach the different tactics and strategies of the scientist for solving problems and forming concepts.
2. To develop creativeness in students.
3. To provide for the individual growth of the student in knowledge, independent thinking, and self-direction.
4. To individualize instruction, thus helping each student develop in science to the utmost of his capacity and ability.

Students should be made to realize that there is no single scientific method, and that, in actual practice, scientists do not follow one particular method. They should learn to identify problems and solve them in order to form concepts.

Creativeness is the tendency of the individual to make novel adjustments. It is also the ability to synthesize previously unrelated elements of experience into a dynamic, unified whole. The authorities feel that all normal human beings have the capacity for creativeness.

Science instruction should make it possible for the individual to grow in knowledge, independent thinking, and self-direction. One of the most important objectives of science teaching is that the student should gain in knowledge. Individual thinking and the student's ability to plan and direct his own life are also important.

Since no two students are alike, there must be provision for the wide range of individual differences of all learners in their need and ability.

Evaluative Criteria for Science Projects

Student projects should be evaluated according to the objectives of science teaching. Unless one knows what to look for in a science project, evaluation is difficult.

Understanding the Tactics and Methods of the Scientist.

A scientific project should show that the student has used some of the tactics and strategies of the scientist in solving his problem and in forming new concepts. Some of the methods the student scientist could use are: (1) the planned investigation, (2) reflective thinking, (3) inspiration, (4) the "educated guess," (5) trial-and-error, (6) the chance discovery, and (7) reference to authority. The scientist may use some or all of these in his investigation.

The planned investigation. The planned investigation should include some or all of the stages of scientific inquiry. It might include some or all of the following: observing nature or surroundings; describing and classifying data; recognizing a problem; using inductive logic to devise experiments and test hypotheses; making use of the control in an experiment; and using deductive logic when laws are discovered or assumed.

Reflective thinking. Reflective thinking may be used in many phases of the investigation. Reflective thinking is that kind of thinking which may appear when a problem arises that finds no ready solution. According to the literature, the student who is skillful in this kind of thinking can discover and clearly define problems. That is, he is curious, but does not try to solve problems for which there are no data; he differentiates between authoritative and non-authoritative sources of information; he observes accurately in laboratory or field work; he shows discrimination in the selection of data and reasonably interprets the data; he selects the hypothesis which best explains the data; he reaches justifiable conclusions which do not claim too much or too little from the data; he is resourceful in attacking the problem and flexible enough to criticize his procedures at any point and to revise his tactics and strategy; he can formulate and carry out a plan of action even if it is based on inconclusive evidence and tentative judgments; he recognizes the possible existence of errors in measurement.

Inspiration. Associated with reflective thinking, another scientific method for attacking problems successfully is inspiration. There are five stages in this method. They are: preparation, incubation, intimation, illumination, and verification. During the preparation stage, the problem is investigated in all directions. In the second stage, there is no conscious thinking about the problem. Preceding the illumination stage, there is a moment when the individual realizes that the answer is coming. During the verification stage, the validity of the idea is reduced to exact forms by conscious use of discipline, attention and will.

The "educated guess." When a scientist uses an "educated guess" to solve a problem in an investigation, he is really playing a hunch. This method is used when there is no apparent solution to the problem. It is based upon knowledge about the problem. Muscular dystrophy and the Bohr theory of the atom were discovered by this method.

Trial-and-error. The trial-and-error method is used by the scientist when he does not have any clues for the solution of a problem. The scientist tries different procedures in attempting to solve the problem. It is usually a slow and unsatisfactory method. Though unscientific, it is still the method best suited for certain kinds of science problems. New antibiotics and quinine were discovered by this method. It is also being used in the fight against cancer.

Accidental discovery. New concepts may be discovered by the scientist accidentally. Some of these concepts led to the discovery of Uranus, the development of penicillin, the discovery of the cause of diabetes, and the discovery of X rays by Roentgen.

Reference to authority. The work of past investigators should be referred to during the investigation. Immediately upon starting the research, the young scientist must read as much about his area of investigation as possible. As he reads, the student should make observations and initiate experiments. However, it is not scientific to use library research as the only tactic in solving a problem.

Developing new concepts, problems. Any scientific investigation should result in the formation of new concepts and problems for the investigator to work on.

Using a logbook. One of the most important means of evaluating the student's tactics and strategy in problem solving is by analyzing his logbook. A scientist should make a record of all he does. He can never tell at the moment of observation whether some occurrence will later be important to his conclusions for the project.

Making a final written report. Since it is necessary that a scientist pass on his information to others, a written report should be included as a part of the science project.

Making a final written report. Since it is necessary that a scientist pass on his information to others, a written report should be included as a part of the science project.

Achievement of Creativeness.

Creativeness is important in all aspects of project work. According to the literature, formulating the hypothesis is the most creative aspect of research—whether the hypothesis relates to defining a problem, to determining a mode of attack, to establishing categories for data, or to making deductions.

Other Kinds of Individual Growth for the Student.

In evaluating the individual growth of the student, such things as knowledge gained and grasp of the subject being studied, self-direction, independence of thinking, and the mental approach to the problem should be considered.

Through questioning, the student's understanding of the subject being investigated should be determined. He should have a good understanding of his particular field.

An important responsibility of education in a democracy is to promote the student's ability to plan and direct his own life. If while working on a project, a student has used his time efficiently, employed efficient work habits, mastered the necessary working skills or abilities, was not easily distracted, was neat, orderly, and thorough in his work, then he has demonstrated his capability for self-direction.

The student demonstrates independence in his project when he questions authority, not rebelliously, but in terms of the qualifications of that authority; when he discovers his own facts and hypotheses instead of being forced to depend on others for their thoughts; when he maintains reservations in accepting the conclusions of others until he has made his own investigations; when he maintains an open mind and is willing to change his opinions when confronted with new evidence; when he is tolerant of the opinions of others; when he is skeptical about his own generalizations and hypotheses and continually strives to substantiate them; and when he checks and rechecks the data in attempting to resolve any conflicting conclusions.

The literature indicates that in order for a person to succeed in science, he must have the proper mental qualities. Genius is not necessary. The attributes needed are clarity of mind, a combination of imagination and caution, of receptivity and skepticism, of patience and thoroughness, and of ability to finalize, of intellectual honesty, of a love of discovery of new knowledge and understanding, and of singleness of purpose.

To summarize, the evaluation of an independent study project in science should be based upon the methods and tactics used, the creativeness expressed, and the individual growth of the student scientist.

Specifically, in evaluating the tactics used by the student scientist, it should be determined whether the tactics used were appropriate for the problem. Since no two problems are alike, no one method can be applied invariably to all problems.

Other things to consider in evaluating the tactics used are: (1) whether the problem was stated simply, clearly and concisely, (2) whether the investigation was planned well, (3) whether the investigation was carried out well, (4) whether the observations were empirically obtained by observations and experiments, (5) whether the observations were accurate, (6) whether the data were grouped and classified properly, (7) whether the hypotheses formed concerning the solution of the problem accounted for a fair part of the available information, since some of the data might be incorrect or irrelevant, (8) whether the apparatus was designed appropriately for the experiment, (9) whether the apparatus works properly, (10) whether the student has tested each of his hypotheses and eliminated the ones which do not help to solve the problem, (11) whether he tested his ideas again and again, and checked them against the work of others, (12) whether objective measurements were used, for which the limits of accuracy were known by the student, and subjective measurement clearly described, (13) whether the observations and experiments can be verified, (14) whether the concepts formed from the data and from the solution of the problem were sound, and (15) whether new problems and experiments were suggested from the solution of his problem.

Creativeness should be evaluated by analyzing the student's logbook. It should be evaluated in terms of the manner by which the student's problem originated, how the hypotheses were formed, how the hypotheses were tested, how the data were collected, organized and interpreted, how the generalizations were drawn, how the apparatus was designed and improved, and how the conclusions were drawn and whether or not new concepts, experiments, and problems for future work resulted from the total effort.

Program Development in Unified Science

IRWIN L. SLESNICK and VICTOR SHOWALTER

Science Teachers, The University School, Center for School Experimentation,
The Ohio State University, Columbus, Ohio

(DECEMBER 1961)

THE TEACHING of secondary school science has rested upon a content organization of physics, chemistry, and life science for as long as science has been a part of the high school curriculum. The time seems at hand for the secure and sacred science disciplines to merge in depth by design. The results of such mergers will be courses of study that dissolve the partitions which have unnecessarily departmentalized unifying science concepts.

During the past few years specialists in physics, chemistry, and biology, in separate convocations, have identified the solid core of their respective disciplines and have adapted these bodies of knowledge and experience for the high school student. Currently, however, the established discipline organization of science is being challenged. Matter, energy, and life are not discrete studies for either the specialist or the generalist. The structure of science has long been recognized as a rapidly converging compendium which increasingly promises to fuse into unified concepts of the universe. In fact the ultimate goal of science is to produce a single theory on a cosmic scale to account for all phenomena. The major concepts of science are incompletely understood unless studied within the context of their interrelatedness.

Biological concepts are chemical, physical, geological, and psychological. The laws of thermodynamics permeate the content cores of the Chemical Bond Approach, the Biological Sciences Curriculum Study, and the Physical Science Study Curriculum materials. The traditional sciences exhibit many similarities in process. The construction of models,

either physical or mathematical, is the creative heart of all science. The nature of science is interdisciplinary.

Prior to the appearance of the *Thirty-first Yearbook of the National Society for the Study of Education* (Part I, 1932) much had been written about the spiraling development of concepts from lower grades to higher grades. In some instances a spiraling core of concepts has been explicated and applied. Certain school systems can display in syllabi and classrooms, vertical threads of concept continuity. Fewer schools can demonstrate horizontal structures which fuse merging concepts. The most notably successful precedent of science integration during the past century has been the union of botany and zoology to form biology. Physics and chemistry have been united on occasion only to lose acceptance through prestige pressures of the established disciplines. Originally, the efforts of the Physical Science Study Committee were aimed toward a two-year sequence of fused chemistry and physics. Consensus regarding the cause of the rapid extinction of general science is that it never had an internal coherence, having been only a hodgepodge of unrelated facts pilfered from the different kinds of science. An examination of general science textbooks reveals that they are largely a collection of preview studies of the differential sciences.

To propose that the out-dated boundaries between the science disciplines be dissolved in a modern curriculum is no longer visionary. The spiraling concepts of science which dangle vertically must now be crosswoven by a horizontal organization that gives unity, strength, and respectability to a curriculum. Teachers with a desire to work on the frontiers of science education might consider program development through a unified approach to the teaching of science.

The Program

One program now under way began in 1959 at the Center for School Experimentation at the Ohio State University. An integrated-fusion high school science curriculum (grades 9-12) is being developed and tested by the staff of the Ohio State University School. Educators and scientists in the role of consultants lend a national scope to the project. The project attempts in a four-year sequential program to fuse the subject matter and method of the formerly independent high school studies of life, matter, and energy into a unity of relationships. The first two years of the sequence, Science I and Science II have been incorporated into the University School program and are required of all ninth and tenth graders, respectively. During the 1961-62 school year, elective Science III was initiated and the following year the more specialized Science IV will begin. Each year a traditional science course is being replaced. The advantage of this curriculum reorganization can only be predicted. Evaluative measurement must await further refinement. Yet, it is believed that the content coverage of the four-year sequence should eventually exceed traditional coverage since duplication and overlap will be avoided. Moreover, all secondary school students should experience depth and breadth in studies involving matter, energy, and life. In the past, only the "science major" experienced such depth and breadth. The unique outcome of this horizontal organization, however, is that student exposure to science becomes a single, dynamic, orderly, understandable, controllable structure—not an archipelago of diverging or static islandic disciplines.

Organization

The structure of Science I is founded upon the interrelatedness of matter, energy, and life. Students inductively and deductively discover that chemical elements, forms of electromagnetic radiation, and species of plants and animals can be naturally classified on the bases of distinguishing properties, and, subsequently, ordered into periodic tables, spectra of electromagnetic radiation, and phylo-genetic trees. The student with a minimum of facts discovers theoretical schemes that reduce the array of endless diversity in the universe to a unity of relationships.

Having grasped the idea of orderliness of the universe in terms of component entities, students are ready to deal with concepts that interpret natural phenomena in broad terms. There are certain fundamental generalizations of nature to which the student is naturally led. The laws of transformation of matter and energy set the pattern for the subsequent study of the sun. Elements of the sun undergoing nuclear changes release energy that literally controls the earth. Photosynthesis and weather are studied as two processes wherein a planet reacts to a star or other planetary objects.

Science II has also been freed from restrictive discipline boundaries. The depth teaching of the facts and mechanism of geologic and organic change are concurrent. The teaching of oxidation (reaction chemistry) fuses with respiration (biology), as do studies of nerve physiology with electrochemistry.

In the latter unit for example, students begin with a study of the case history, *Frogs and Batteries*. Here they experience the discoveries of early physicists, biologists, and chemists as they seek the sources of "animal electricity." On the modern scene they continue to see that nerve physiology is a correlation of depth physics and chemistry in the site of an organism.

The content of Science III is being organized in three principal and sequential units. Each of the units is integrated (*i.e.*, fused) by a single theme that is common to the structure of all science. Each theme reflects the dynamic nature of science and its processes.

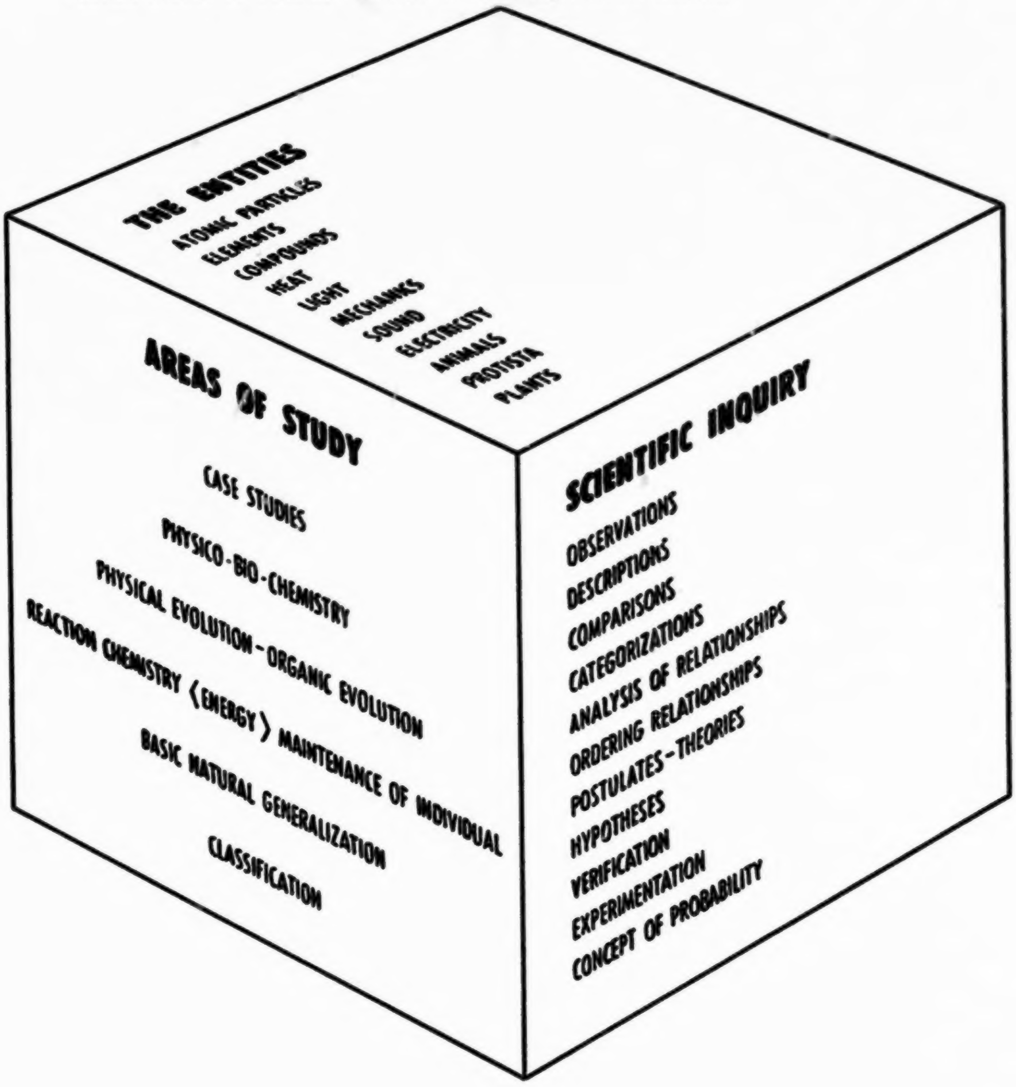
Specifically, the three themes in order of presentation are: (1) Quantification, the foundation of science; (2) Human Senses, the way to science; and (3) Models, the expression of science.

Each unit borrows heavily from other organized attempts to modernize the science curriculum. For example, kinematics as developed by the Physical Science Study Committee is an integral part of the larger unit on quantification. Electron configuration of atoms and the geometrical results of bonding with other atoms as developed by the Chemical Bond Approach fill a major portion of the unit on models. Biological processes and behavior provide many opportunities for students inventing techniques of quantification. Though Science IV will not become a reality for another year, it is conceived as a continuation of Science III. Presumably the first unifying theme to be exploited will be, Equilibrium.

The prospects of teaching unified science in the high school raises many questions. Is the breadth preparation of science teachers sufficient to enable them to teach secondary school science in fused context? Are the current school science facilities adaptable to this approach? Is unified science suited for just one kind of student? Who should develop unified science programs, using what concepts and for what grade levels?

Small pilot programs in unified science are known to be under way in several states. Their impact upon the current horizontal and vertical organization of school science will likely be felt, as more schools endeavor to adjust their curricula to the natural integrality of science.

Cubical Model of authors' concept of teaching unified science.


THE ENTITIES
ATOMIC PARTICLES
ELEMENTS
COMPOUNDS
HEAT
LIGHT
MECHANICS
SOUND
ELECTRICITY
ANIMALS
PROTISTA
PLANTS
AREAS OF STUDY
CASE STUDIES
PHYSICO-BIO-CHEMISTRY
PHYSICAL EVOLUTION-ORGANIC EVOLUTION
REACTION CHEMISTRY ⟨ENERGY⟩ MAINTENANCE OF INDIVIDUAL
BASIC NATURAL GENERALIZATION
CLASSIFICATION
SCIENTIFIC INQUIRY
OBSERVATIONS
DESCRIPTIONS
COMPARISONS
CATEGORIZATIONS
ANALYSIS OF RELATIONSHIPS
ORDERING RELATIONSHIPS
POSTULATES-THEORIES
HYPOTHESES
VERIFICATION
EXPERIMENTATION
CONCEPT OF PROBABILITY

SECTION 2
Classroom Instruction Ideas

PART A
Earth and Space Sciences

A Unit on Rocks and Minerals

HENRY J. FOCACCI and THEODORE J. HUFF

Science Teachers, Public Schools, Paterson, New Jersey

(MARCH 1961)

I. Approach—An Introduction to Rocks and Minerals

HAVE YOU EVER wondered how rocks were formed? Ever since the first man became curious about rocks (geology) and minerals (mineralogy), he has been fascinated by the mysteries of how and why they came to be.

During past millenniums, the earth has undergone many changes which have shaped the natural rock formations we witness today. Understanding the earth's structure and composition is a valuable asset in the study of rocks and minerals. There is a difference between superficial deposits and bedrock. Superficial deposits (1) include loose rock and soil which make up the outer surface of the earth's crust; bedrock (2) is the solid rock beneath, grading downward to the earth's mantle (3), and eventually to its core (4). The fundamental nature of these layers was illustrated and discussed in an article by G. P. Woollard in the September 1960 issue of *The Science Teacher*.

It is this bedrock, divided into the three categories called igneous, sedimentary, and metamorphic, with which we are mainly concerned here.

Igneous rock, which is Latin for "fire" rock, is the basic stuff from which all other rock formations are eventually derived. These rocks are the solid (frozen) equivalents of volcanic lavas and other once-molten substances. They cover large areas of the earth and have such names as granite, diorite, pumice, pegmatite, obsidian, felsite, and basalt.

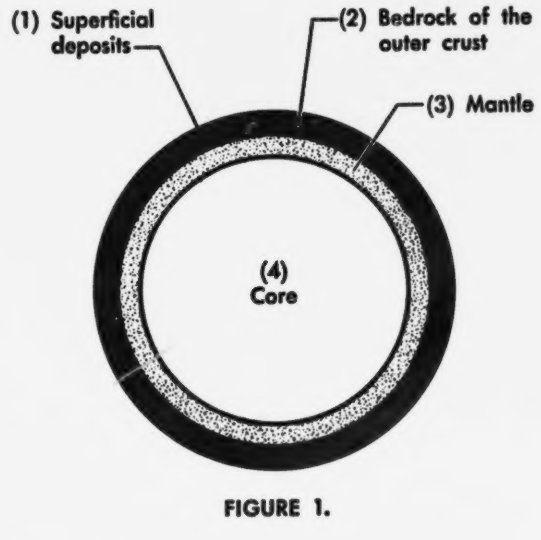


FIGURE 1.

The weathering or breakdown of igneous rock by wind, water, and glaciers causes certain sediments to be washed away and later deposited elsewhere. The conglomeration and cementing of these sediments, or the crystallization of substances from solution in seas or lakes, form our second group of rocks, called sedimentary rock. These rocks, many of which contain fossils, are characteristically stratified. Shale, limestone, sandstone, coal, and conglomerate are examples of sedimentary rock.

Due to the pressure, increased temperature, and chemical action affecting igneous and sedimentary rocks that are deeply buried or squeezed by mountain-building processes, we now have the third type of rock called metamorphic from the Latin word signifying that this rock has undergone change in texture and mineral composition. Metamorphic rocks are ordinarily banded or laminated and commonly compact and crystalline. Examples are slate, gneiss, marble, and quartzite.

Rocks are composed of one or more minerals or mixtures of minerals. A mineral, on the other hand, is composed of a fixed arrangement of compounds or elements. Minerals are commonly crystallized. Throughout the centuries, minerals and rocks have served man as raw materials, tools, sources of energy, and for decorative and other purposes. Some well-known minerals are salt, diamond, topaz, quartz, feldspar, fluorite, calcite, gypsum, and talc.

Closely related to rocks and minerals are ores which are rock or mineral deposits from which metals such as gold, silver, copper, platinum, or lead can be obtained commercially.

II. General Objectives

1. To develop a consciousness of the importance of rocks and minerals.
2. To explore this area of rocks and minerals.
3. To understand the three major classes of rocks, their classifications, and uses.

4. To provide experiences which will give practice in developing skills and habits in understanding and appreciating the uses of rocks and minerals.

III. Specific Objectives

1. To understand how rocks are formed.
2. To acquire a knowledge of the general characteristics of rocks and minerals.
3. To learn how rocks and minerals are related to other things in nature.
4. To understand what fossils are.
5. To ascertain how important rocks and minerals are to the earth.
6. To understand how man has learned to use rocks and minerals.

IV. Skills

1. Develop ability to think, to evaluate, write, and speak clearly, constructively, and creatively about rocks and minerals.
2. Learn to comprehend vocabulary necessary to the unit of study and to spell terms correctly.
3. Develop ability to read critically the material in this area of study.
4. Develop ability to express oneself through illustrative material.

V. Habits

1. Develop good work and study habits.
2. Develop the habit of working with others.
3. Develop the habit of reading purposive writings.
4. Develop the habit of collecting and organizing data.
5. Develop the habit of perseverance.
6. Develop the habit of being a resourceful person.
7. Develop the habit of being an original thinker and planner.
8. Develop the habit of dependability and accuracy.
9. Develop the habit of using good oral and written language.
10. Develop the habit of checking evidence before forming a conclusion.

VI. Attitudes

1. Pupil becomes aware of the importance of rocks and minerals.
2. Pupil learns to be persistent in his search for truth about rocks and minerals.
3. Pupil learns to keep an open mind about scientific knowledge relating to the study of rocks and minerals.
4. Pupil learns the value of the scientific method in general problem solving.
5. Pupil acquires intellectual curiosity about rocks and minerals and their relationship to other forces of nature.
6. Pupil learns the need to go to reliable sources for information and to formulate tests of reliability.

VII. Known Concepts

1. Superficial deposits consist of loose rock and soil which make up the outer surface of the earth's crust.
2. Bedrock consists of the solid rock beneath.
3. Igneous rocks are made by heat.
4. Sedimentary rocks are formed from sediment deposited from water, air, or ice.
5. Metamorphic rocks are igneous and sedimentary rocks changed by heat and pressure.
6. Some minerals are more useful to man than others.
7. Rocks are used for many purposes including building materials, road making, and industrial uses.
8. Fossils are the stony remains or impressions of animals and plants in the rock.
9. Minerals are pure, commonly crystallized substances, many of which are useful to man.
10. Ores are rock or mineral deposits from which metals can be produced commercially.
11. Some rocks and minerals can be used as jewels.
12. Igneous rocks are the solid equivalents of once-molten substances. They are commonly massive and crystalline.
13. Sedimentary rocks are stratified.
14. Metamorphic rocks are characteristically massive or foliated.

VIII. Concepts to Be Developed

1. Rocks and minerals can be identified in various ways.
2. Rocks are the building material of which the earth is composed.
3. Rocks are commonly made of mineral crystals which have grown together.
4. Minerals are naturally occurring substances having a definite chemical composition and characteristic physical structure.
5. There are thousands of kinds of minerals and hundreds of kinds of rocks.
6. Luster, color, and crystal form characterize the general surface appearance of minerals.
7. Hardness is the resistance that certain minerals have to being scratched by other substances.
8. Cleavage is the smooth breakage of a mineral in given directions.
9. Fracture is the state of a mineral breaking unevenly and not along cleavage surfaces.
10. The streak of a mineral is the mark made by testing it on the back of a piece of tile or unglazed porcelain.

11. Some minerals fluoresce under ultraviolet light; the luminescence of certain types can be produced through the rays of such lights.

IX. Activities, Observations, Experiments

1. List the vocabulary that relates to the unit of study.

2. Make a chart of the more common rocks and minerals, their uses and their characteristics.

3. Keep a record of current news items about rocks and minerals and their uses in the world today.

4. Arrange a display of rocks and minerals with proper labels for identification.

5. Read information about rocks and minerals from various sources such as science texts, supplementary science materials, encyclopedias, etc.

6. Conduct a class discussion and demonstration of the following:

While investigating the various means of identifying minerals, it is necessary to notice the particular characteristics possessed by them: luster, color, hardness, cleavage, fracture, and specific gravity.

Luster and color, which are produced through various means, pertain to the general surface appearance of minerals. These two features are very closely allied.

Hardness is the resistance that certain minerals have to being scratched by other substances. Diamonds can be scratched only by other diamonds; jade can be scratched by quartz; gypsum by fingernails; calcite by a penny; feldspar by a sharp knife; and quartz by a hardened steel file.

Cleavage is the smooth breakage of a mineral in given directions. Mica, a perfect example of cleavage, can be peeled into very thin sheets.

Fracture, on the other hand, is the state of a mineral breaking unevenly without any definite direction.

The power of magnetism influences some minerals that contain iron, nickel, or cobalt.

7. Place some small chips of granite secured from a quarry or a stonecutter in a small muslin bag and strike the bag several times with a hammer. Examine the powdered fragments under a magnifying glass. The little shiny flakes will be mica; the white and pink particles will be quartz and feldspar.

8. Figure the specific gravity of a mineral—the ratio of the weight of a mineral to the weight of the same volume of water. Weigh the mineral and then drop it into a graduated container partly filled with water. Read the volume of water displaced. This is also the volume of the mineral. One cubic centimeter (or, better, milliliter) of water weighs almost exactly one gram. Divide the weight of the mineral by the volume to discover how much one cubic centimeter would weigh, and this (divided by one) is the specific gravity. This is one of the best clues for identifying a pure mineral.

9. Through a class project, investigate the following facts about luminescence. One of the most fascinating characteristics of minerals is their ability to glow in the dark. There are different ways in which minerals can glow, and some give an added clue to identity. The luminescence may be fluorescent, phosphorescent, thermoluminescent, or triboluminescent. Scheelite, for example, may fluoresce bright blue. Phosphorescence occurs when the mineral continues to glow after it has been exposed to an ultra-violet light and the light has been turned off (for example, willemite). Thermoluminescence applies to the condition where the mineral, when heated, gives off light in a darkened room. Triboluminescence occurs when a mineral, scratched in the dark, shows a line of light, as does sphalerite. Place several small pieces of fluorite in a baking dish with a glass cover and heat gently. The pieces of fluorite will bounce about giving off sparks of light.

10. Explain the difference between tenacity and hardness. Tenacity differs from hardness in a mineral. It is the way a mineral holds together. Jade has tenacity, for example. A diamond is hard, yet if struck with force it can be shattered.

11. Discover the oddities among minerals and rocks. Find the meaning and uses of such minerals as garlic stones, seeing-eye metal, weather stone, magnetic stone, cryolite, and gastroliths.

12. To test for calcite, place a few drops of cold, diluted hydrochloric acid on calcite. Bubbles of carbon dioxide will appear, showing that the mineral is a carbonate (contains CO_3). Or test a piece of granite with hydrochloric acid and notice that it does not bubble.

13. Take the class to a museum to see rocks, minerals, and fossils.

14. Make collections of pictures showing rock being quarried for building purposes.

15. Explore a quarry in your neighborhood. Examine the rock ledges exposed. Investigate uses made of rocks in your locality.

16. Show that sandstone is porous. Weigh a dry piece, and then let it soak in water overnight. Weigh it again after you have wiped off any drops of water on the surface. The increased weight is due to water that has occupied pore spaces in the rock. How could you estimate volume of pore space from this?

17. Have a glass jar of water ready. In another dish mix sand, pebbles, small shells, and fine clay or dust. Pour the mixture into the water, and let it settle. Does it settle in layers?

18. You may make an impression of a fossil by pressing a shell or a piece of fern between two layers of clay or plasticene. When you separate the layers, the shell or fern lies on one, and the mark it made shows its shape on the other.

X. Visual Aids

1. Use of films and filmstrips to tell the story of rocks and minerals and their usefulness to man.

2. Use of the opaque projector to show pictures of rocks and minerals.

3. Use of pictures from magazines and other sources to explain rocks, minerals, and their uses.

4. Use of models of building materials from rocks and minerals, as well as actual specimens of rocks and minerals.

5. Making posters and charts illustrating facts about the field of study.

6. Assembling materials and equipment for various experiments with rocks and minerals.

XI. Materials

Specimens of rocks and minerals; acid (vinegar, lemon juice, or hydrochloric); oak tag paper; construction paper; butcher paper for posters and charts and for sketches and diagrams of rocks and minerals; clay or plasticene; shells; plant leaves; small pans; water; ultraviolet light; display boxes and trays for rocks and minerals; and any other materials needed for experiments and activities listed in this unit of study.

XII. Evaluation

The students were able to discuss major learnings of the unit in class, in a written examination, and in a culminating unit activity—an assembly program entitled "The Earth's Crust." Not only did they learn about rocks and minerals and their importance to man, but many pupils also became interested in rock collecting outside of class time. They felt they would be better collectors since they had acquired a background of knowledge in the identification of rocks and minerals.

The teacher observed that the general and specific objectives of the unit were achieved. Major concepts were developed through pupil participation in experiments and in class activities. Since the study of rocks and minerals was interesting to the pupils, the author believes considerable understanding, enjoyment, and a beneficial approach to scientific problem solving were derived from the unit.

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A Unit on Fossils

WILLIAM H. MATTHEWS III
Professor of Geology, Lamar State College of Technology, Beaumont, Texas

(NOVEMBER 1962)

FOSSILS ARE THE REMAINS or evidence of prehistoric plants or animals that have been preserved in the earth's crust. Through the science of paleontology (the study of fossils), life has been traced from its first clear record—more than 600 million years ago—through its evolution into the more advanced forms of today.

I. Approach—An Introduction to Fossils.

Fossils have apparently attracted man since early times for they have been found in association with the remains of prehistoric men. As early as 450 BC certain Greek philosophers noticed fossil sea shells far from the ocean. Some of them correctly concluded that these objects represented once-living animals and that the seas had formerly covered the area in which they were found. During the Dark Ages, fossils were alternately explained as freaks of nature, the remains of attempts at special creation, or devices of the devil placed in the rocks to lead man astray. These superstitious beliefs hindered the development of paleontology for centuries. But for the last 150 years, fossils have been widely recognized as the remains of ancient life and much has been learned from them.

Most fossils occur in *sedimentary* rocks. Such rocks were deposited by water or wind in oceans, lakes, streams, etc. Only rarely are well-preserved fossils found in igneous or metamorphic rocks.[1]

Because of the diversity of fossil remains, the paleontologist has made the following divisions within his science:

1. Paleobotany—The study of fossil plants.
2. Invertebrate Paleontology—The study of fossil animals without a spinal column or backbone (clams, snails, etc.).
3. Vertebrate Paleontology—The study of fossil animals possessing a spinal column or backbone (dinosaurs, etc.).
4. Micropaleontology—The study of fossils that are so small that their distinguishing characteristics are best studied under the microscope.

Like living plants and animals, fossils are classified by the Linnean system of binomial nomenclature. This provides a means of grouping organisms together according to their relationships and similarities.

In general, an organism will not be fossilized unless (a) it possesses hard parts, (b) the remains escape immediate destruction after death, and (c) it is buried in a medium capable of preservation. Thus, only a minute fraction of pre-existing organisms have left any record of their existence. In addition, there are gaps in the fossil record of nondeposition or nonpreservation which limit conclusions.

According to their type of preservation fossils are found as (1) original soft parts (rare occurrences such as frozen woolly mammoths); (2) original hard parts (unaltered teeth, bones, shell, etc.); (3) altered hard parts (petrified or "turned to stone," replaced by minerals, or carbonized); and (4) traces of organisms (indirect evidence such as molds, casts, tracks, and related items).

Fossils are useful in a number of different ways, for each specimen provides some indication as to when it lived, where it lived, and how it lived. Such paleontological information is useful in both scientific and economic geological studies.

In studying fossils the paleontologist relies on *uniformitarianism*—the principle that ancient organisms lived under conditions similar to those of their nearest living relative or morphological counterparts. Thus, paleontological studies require the techniques of both geology and biology.

II. General Objectives.

1. To become aware of the great antiquity of the earth.

NOTE: Permission has been granted for use of the photographs from *Fossils: An Introduction to Prehistoric Life* by William Matthews III, published by Barnes and Noble, Inc., New York, 1962.

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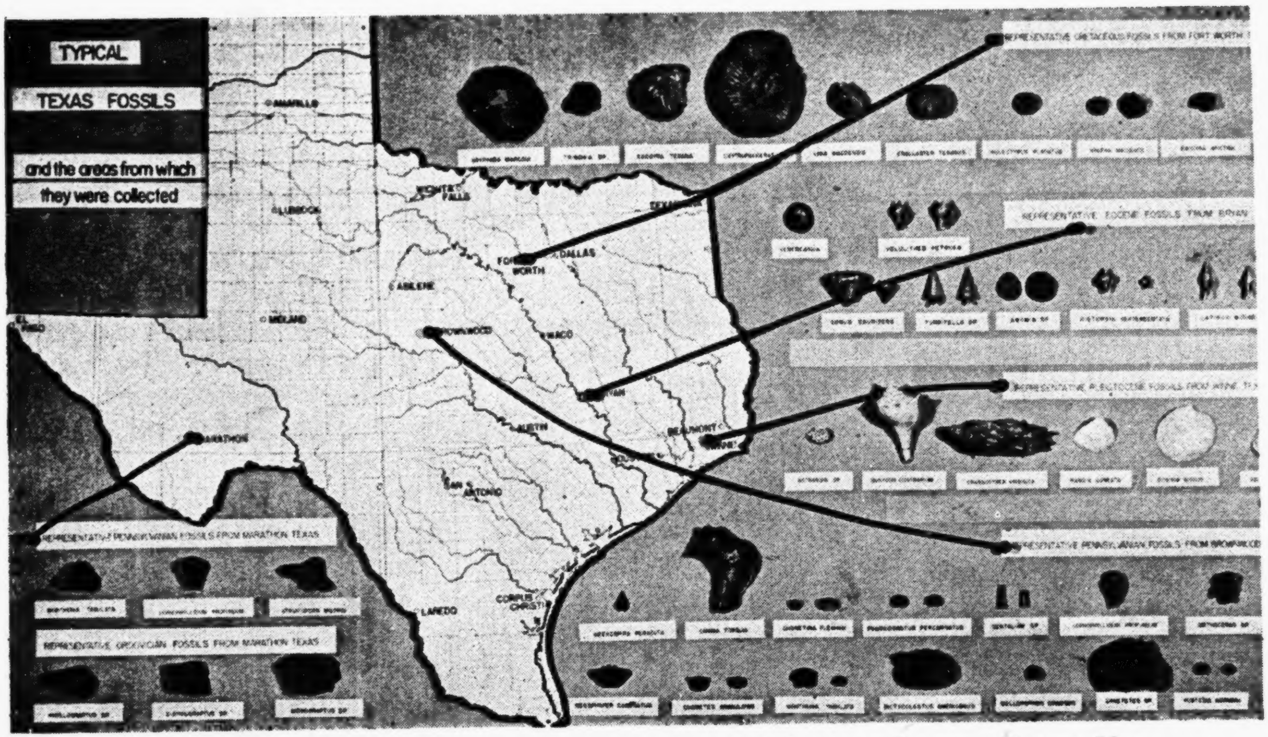
[1] The basic characteristics of rocks and minerals were covered in an article by H. J. Focacci and T. J. Huff, "Science Unit on Rocks and Minerals," *The Science Teacher*, 28:25, March 1961.


TYPICAL
TEXAS FOSSILS
and the areas from which they were collected
AMARILLO
LUBBOCK
WICHITA FALLS
TEXARKANA
FORT WORTH
DALLAS
ABILENE
MIDLAND
EL PASO
BROWNWOOD
WACO
BRYAN
AUSTIN
BEAUMONT
MARATHON
SAN ANTONIO
LAREDO
CORPUS CHRISTI
REPRESENTATIVE CRETACEOUS FOSSILS FROM FORT WORTH
REPRESENTATIVE EOCENE FOSSILS FROM BRYAN
REPRESENTATIVE PENNSYLVANIAN FOSSILS FROM BROWNWOOD
REPRESENTATIVE PERMIAN FOSSILS FROM MARATHON TEXAS
REPRESENTATIVE ORDOVICIAN FOSSILS FROM MARATHON TEXAS

Regional display of fossils. Representative fossils from selected areas in Texas are illustrated here.

2. To understand the nature and source of fossils.
3. To appreciate the role of fossils in the interpretation of earth history.
4. To learn the importance of organic evolution in the development of present-day plants and animals.

III. Specific Objectives.

1. To become acquainted with the science of paleontology.
2. To acquire some knowledge of the general characteristics of fossils and the plants or animals that they represent.
3. To learn where and how to collect fossils.
4. To learn how to identify fossils.
5. To understand how fossils are useful to man.

IV. Skills.

1. Develop ability to think, write, and speak intelligently about fossils.
2. Acquire and understand vocabulary necessary to the unit of study and to spell terms correctly.
3. Develop ability to find and understand reference materials on fossils.
4. Develop observational powers on fossil-collecting trips.

V. Attitudes.

1. Student becomes aware of the true meaning of fossils.
2. Student learns the value of the scientific method in interpreting fossils and earth history.
3. Student develops some concept of the immensity of geologic time and its relation to absolute time.
4. Student becomes intellectually curious about fossils and their significance in deciphering earth history.

VI. Facts and Ideas.

1. Fossils are the remains or evidence of prehistoric plants or animals that have been preserved in the earth's crust.
2. Paleontology—the study of fossils—has provided science with a key to geologic history.
3. Unless strata have been disturbed, older rocks (containing relatively primitive fossils) underlie younger rocks. Fossils become more advanced evoluntionarily and complex morphologically in the younger strata.
4. Originally thought to be freaks of nature, fossils are now known to be the remains of once-living organisms.
5. Most fossils occur in sedimentary rocks.
6. Only a minute fraction of the earth's prehistoric inhabitants have become fossilized.
7. The fossil record is not complete; fossils may be destroyed by (a) metamorphism, (b) erosion, or (c) dissolved by ground water.
8. Many fossils are petrified—literally turned to stone as pore spaces in the organic matter became

filled with mineral-bearing solutions. (Example: Petrified wood.)

9. Some fossils have been preserved by minerals which have replaced the original bones, shell, or other hard parts. (Examples: Shells replaced by iron compounds; bones replaced by silica or calcite.)

10. Many organisms, especially plants, have undergone carbonization. Such fossils occur as carbon residues. (Example: Fossil plants found in coal deposits.)

11. Fossils consist not only of actual plant and animal remains but of any trace of their existence. (Examples: Molds, impressions of organic remains; casts, formed when molds became filled with sediment; tracks, such as dinosaur footprints.)

12. Paleontologists and biologists use the same system of classification—closely related fossils are grouped together according to the rules of Linnean, or binomial classification.

13. Fossils are used in a variety of ways:

a. They provide evidence of life of the geologic past.

b. Certain fossils lived but a short time, yet attained widespread distribution. These fossils, sometimes called *guide*, or *index* fossils, are especially useful in dating and correlating the rocks which contain them (although professional paleontologists place more reliance on community assemblages).

c. Fossils help reconstruct climatic conditions of the geologic past. (Examples: Fossil ferns ordinarily indicate warm humid climates; fossil musk ox or reindeer suggest colder climates.)

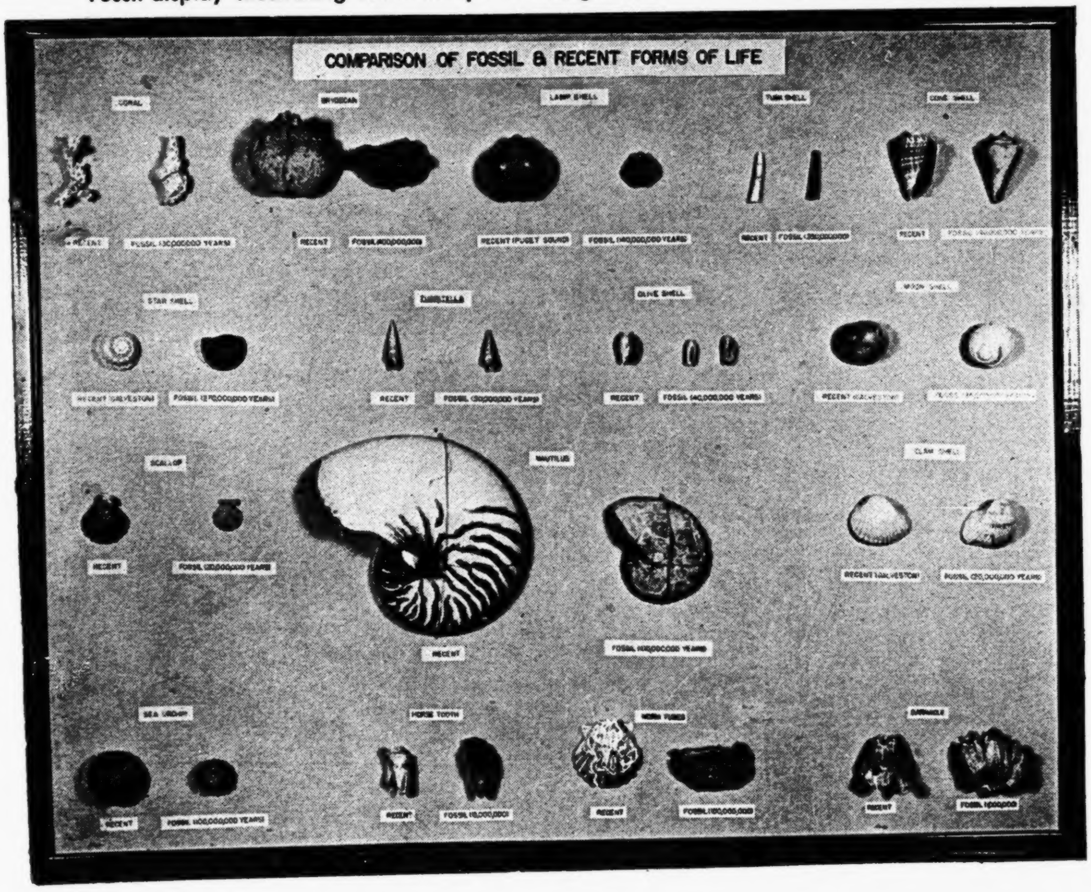
d. The distribution of ancient seas and lands can be determined by a study of fossils. (Examples: The presence of marine fossils suggests marine deposition in an area; conversely, remains of terrestrial forms—trees, mammals, birds—may be indicative of continental deposits.)

e. Fossils offer one of the strongest lines of evidence to support the theory of organic evolution. (Example: Development of the horse from a morphologically simple primitive form to the modern horse is especially well known.)

f. Certain fossils have extensive practical application. (Examples: Fossils may help locate deposits of coal, ore, and petroleum; certain fossiliferous limetones make attractive building stones; *microfossils*, fossils so small that many escape damage by the drill bit, are useful in petroleum exploration.)

14. Plants and animals of the past are believed in general to have lived under conditions similar to those required by related or analogous living organisms. This principle, known as uniformitarianism, may be simply stated as "the present is the key to the past."

Fossil-display illustrating relationships of living forms to comparable fossil specimens.



VII. Activities, Observations, and Experiments.

The following activities [2] may be done individually, in small groups, or by the entire class. Local resource people (practicing geologists, museum personnel, geology teachers, etc.) can be most helpful in a unit of this type.

1. Keep a notebook of current news items about fossils.

2. If there are fossiliferous rocks in your area, make a collection of typical fossils found there. Several states have fossil-collecting guides that provide paleontological information for the state concerned. Write your state Geological Survey to learn if such a guide is available. Collect enough fossils so that exchanges can be made for fossils from other parts of the state. Write teachers and students in other areas and suggest that such an exchange be made and continued.

3. As a group project, use fossils received in exchange to prepare a display of representative fossils from your state or particular area.[3]

4. If a collection cannot be made, purchase a study collection of fossils, take the students to a museum, or show them pictures of fossils.

5. Explain how fossils are formed. Obtain by field collection, exchange, or purchase, specimens that show the various types of fossil preservation. Compare and discuss the differences between them.

6. Discuss classification of fossils (phylum, class, genus, and species). Refer to any biology textbook for details of this classification. An effort should be made to group broadly (according to phylum and class) all fossils that have been collected. Students who are particularly interested in this part of the study should be encouraged to make their own collection and classify some of the local fossils.

7. Conduct a demonstration and prepare a display illustrating the comparison between living and fossil forms.

8. Demonstrate how casts and molds are formed:

a. Cover the bottom of a cardboard box with modeling clay to a depth of several inches.

b. Press a small clam or snail shell deeply into the clay.

c. Lift the shell out carefully so that a clear imprint remains.

d. Mix plaster of Paris to consistency of thick cream and fill mold.

e. After plaster has hardened, remove the *cast* from the *mold.*

9. Demonstrate how *petrification* or *permineralization* occurs. Melt paraffin and use it to impregnate a cellulose sponge. Mention that the paraffin fills the pores of the sponge making it more resistant to chemical and physical deterioration. It has, in a sense, been permineralized.

10. Have students observe footprints, bird tracks, or leaf impressions that have been left on freshly poured concrete. These simulate "traces" of organisms. Ask students to speculate as to the circumstances under which they were formed.

11. Read about prehistoric life in science texts, supplementary science materials, encyclopedias, etc.

12. Collect pictures of fossils and display in classroom.

13. Have students prepare a brief written report on the uses of fossils. Emphasize any utilization of fossils in the local area.

14. Make reading assignments in books describing dinosaurs. Later, lead class discussion on this subject.

15. Take students on field trip to a museum. Have them submit a short report giving highlights of the trip.

16. Show class a movie or filmstrip about fossils.

17. Show internal structure of a fossil by grinding away the external surface. Place some carborundum powder on a piece of plate glass. Moisten powder and by means of a circular motion grind away the exterior until the interior surface is visible. Corals, snails, brachiopods, and bryozoans are especially well suited for this experiment which is easy to do.

18. Make plaster models of fossils. Molds can be made from liquid rubber; plaster of Paris poured in mold will harden into a replica of the original. Using water colors, paint specimen to resemble original fossil.

19. Embed fossils in plaster of Paris base. Mix plaster and pour into a shallow tray or pan which has been greased or lined with wax paper. Before plaster completely sets, press fossil into the surface. Specimen should be pressed deeply enough to be held firmly in place.

VIII. Visual Aids.

1. Use films and filmstrips to tell the story of fossils.[4]

2. Use opaque projector to show pictures of fossils.

3. Use pictures from magazines and other sources to explain nature of fossils.

4. Use models of dinosaurs, woolly mammoth, and other prehistoric animals, as well as plaster casts and actual fossil specimens.

5. Use posters and charts to show relationships between recent and fossil organisms and the development of life through geologic time.

IX. Materials.

Specimens of fossils; display boxes, trays and labels; clay or plasticene; plaster of Paris; small

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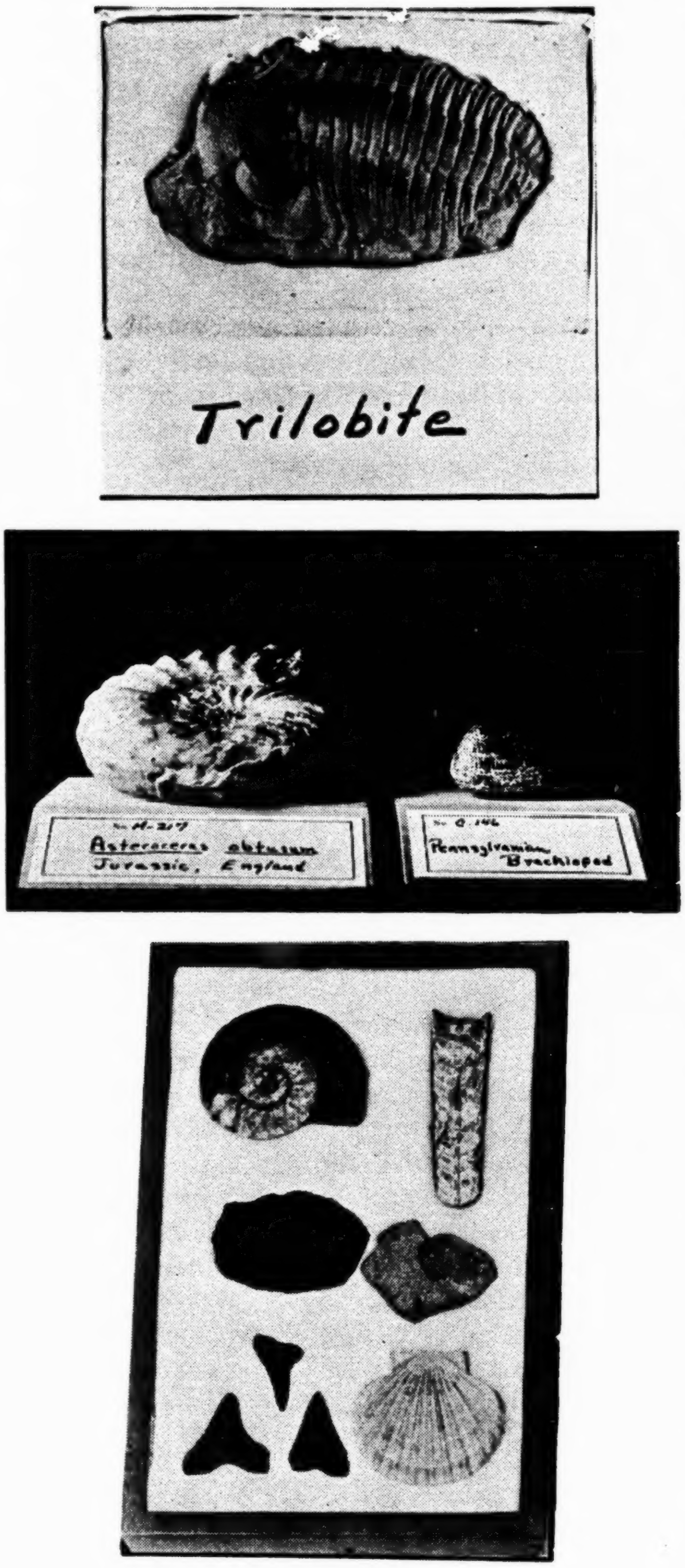
[2] See Reference No. 5 for other activities.

[3] For details on the preparation of this and other teaching exhibits, see Reference No. 6.

[4] See Reference No. 2.



Ways of displaying fossils in the classroom. Top: Plaster cast of trilobite (cast from latex mold); Middle: Fossils on wooden display bases; and Bottom: Fossils in Riker mount.

pans; water; carborundum; sheet of plate glass about six by eight inches; cellulose sponge; paraffin; poster board; and other materials as needed.

X. Evaluation.

1. Were the students enthusiastic and willing to take responsibility for special assignments? Did some want to pursue the study of a particular part of the unit? Did oral and written tests indicate that students had developed accurate concepts?

2. An effective evaluation of the unit can be made through the study of a report or notebook prepared by the student and submitted at the end of the unit. The notebook should include, in the student's own words, the nature of the study, the reason for the study, conclusions reached, description of field trips, experiments, etc. Evaluation of this material will provide some indication as to whether or not the students developed the proper concepts about fossils and geologic history.

XI. Enrichment.

Enrichment for the student can be attained if:

1. Students will exchange information and fossils with students in other areas.
2. Those students interested in classifying fossils can be encouraged to do further collecting and classification. These fossils could form nucleus of a school museum.
3. Students are encouraged to look for fossils while on outings, vacation trips, etc., thereby increasing their knowledge and enjoyment of their surroundings.
4. Students are encouraged to do outside reading and report to the class on some particular phase of the study.
5. Students can develop a science project about fossils.

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Let's Make a Rain Gauge

MATTHEW F. VESSEL

Professor of Biology and Science Education, San Jose State College, San Jose, California

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One of the essential instruments for classroom weather study is a rain gauge. Most schools cannot afford to buy such an instrument and the frequently used home made rain gauge consisting of a funnel and a mayonnaise jar is almost useless. You cannot set out a bucket and measure how much rain fell, for the amount of rain collected during any one rainfall is too small to be measured successfully. Here's a simple yet accurate instrument to measure rainfall which can be made for about 50 cents.

The standard manufactured rain gauge which uses a dip stick consists of a funnel and a cylinder arrangement. The ratio of the *area* of the funnel to the *area* of the inside cylinder is ten is to one. This makes it quite easy to measure the rainfall collected because the cylinder contains ten times the actual rainfall, and the measuring dip stick is calibrated in tenths and hundredths of an inch.

To make a rain gauge comparable to the manufactured type you will need: (1) a plastic funnel about 3″ or more in diameter; (2) a tall narrow bottle such as an olive bottle; (3) an unpainted stick (a 3/8″ soft wood dowel works well); (4) to borrow a graduated cylinder for measuring liquids in the metric system.

First of all you may have to review some mathematics. The volume of a cylinder can be obtained by following the formula $V = \pi r^2 h$. Because it is easier to compare *volume* and *linear* measurements in the metric system than it is in the English system, we will adapt the formula to the metric scheme. So:

$V =$ volume

$\pi = 3.14$

$$r = \frac{\text{diameter in centimeters}}{2}$$

$h = 2.54$ centimeters (this equals 1 inch)

Suppose that the funnel you bought has a diameter of three inches. (This is 7.6 cm., for each inch equals 2.54 centimeters.)

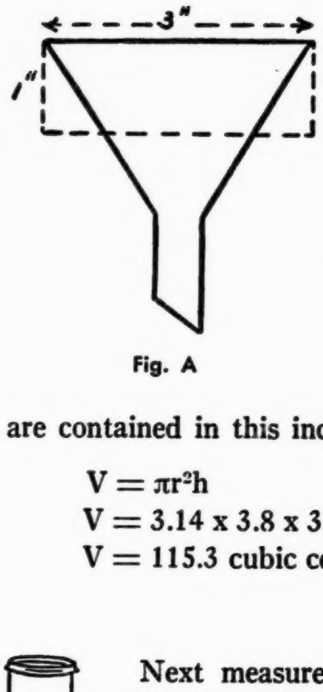


Fig. A

Let us assume that one inch of rain fell and it was collected by this funnel. This would fill a *cylindrical* dish one inch deep and three inches in diameter as shown by the dotted lines in figure A. Using these figures we can now make our calculations to find out how many centimeters of water are contained in this inch of rain.

$V = \pi r^2 h$

$V = 3.14 \times 3.8 \times 3.8 \times 2.54$

$V = 115.3$ cubic centimeters

Fig. B

Next measure out 115.3 cm. of water with the graduated cylinder and pour this water into the olive bottle you plan to use for a rain gauge. (If the inside bottom of the bottle is too irregular, it would be well to melt some wax into it and make a flat surface.) Suppose that the water you measured and poured into the olive bottle looked like the sketch in figure B. Measure the height of this column of water by inserting the measuring stick. Now divide the distance measured on this stick into ten equal parts.* You now have a funnel, a bottle, and a measuring stick which will measure rainfall accurately to tenths of an inch or better.

Demonstrations of Mist, Fog, Cloud, and Rain

FREDERICK W. JEFFS
Bamber Bridge Training College, Lancashire, England

(FEBRUARY 1951)

Mist. Take a large and substantial round-bottomed flask, or a two-liter reagent bottle. Fit it with a one-hole stopper and tube so that air may be compressed in it. Shake up a little water in the flask to insure the presence of plenty of water vapor. Press in the stopper very firmly, connect to a foot or hand pump, and begin compressing. It is advisable to secure the flask so that it is not likely to roll. (Ed. note: We prefer a one-liter, side-neck Erlenmeyer flask and solid stopper.)

After a short time the stopper is driven out with a bang, and a gray mist or cloud appears in the flask. At once replace the stopper and recommence pumping. The mist disappears. Continue pumping until the stopper is driven out once more; the mist reappears.

It is important for the class to realize that the compression-and-decompression is merely a convenient routine to raise or lower the temperature of the air in the flask. The teacher cannot emphasize this too strongly, especially in the lower grades.

The principles illustrated are: (1) when a mass of air is cooled below the dew-point temperature, a cloud or mist may be formed; and (2) if a mass of air in which water particles are suspended in the form of a mist is heated, the mist is likely to disappear.

Fog. Introduce smoke to the flask by lowering in a piece of smouldering rag on a wire. Alternatively, blow in a little cigarette smoke through a tube.

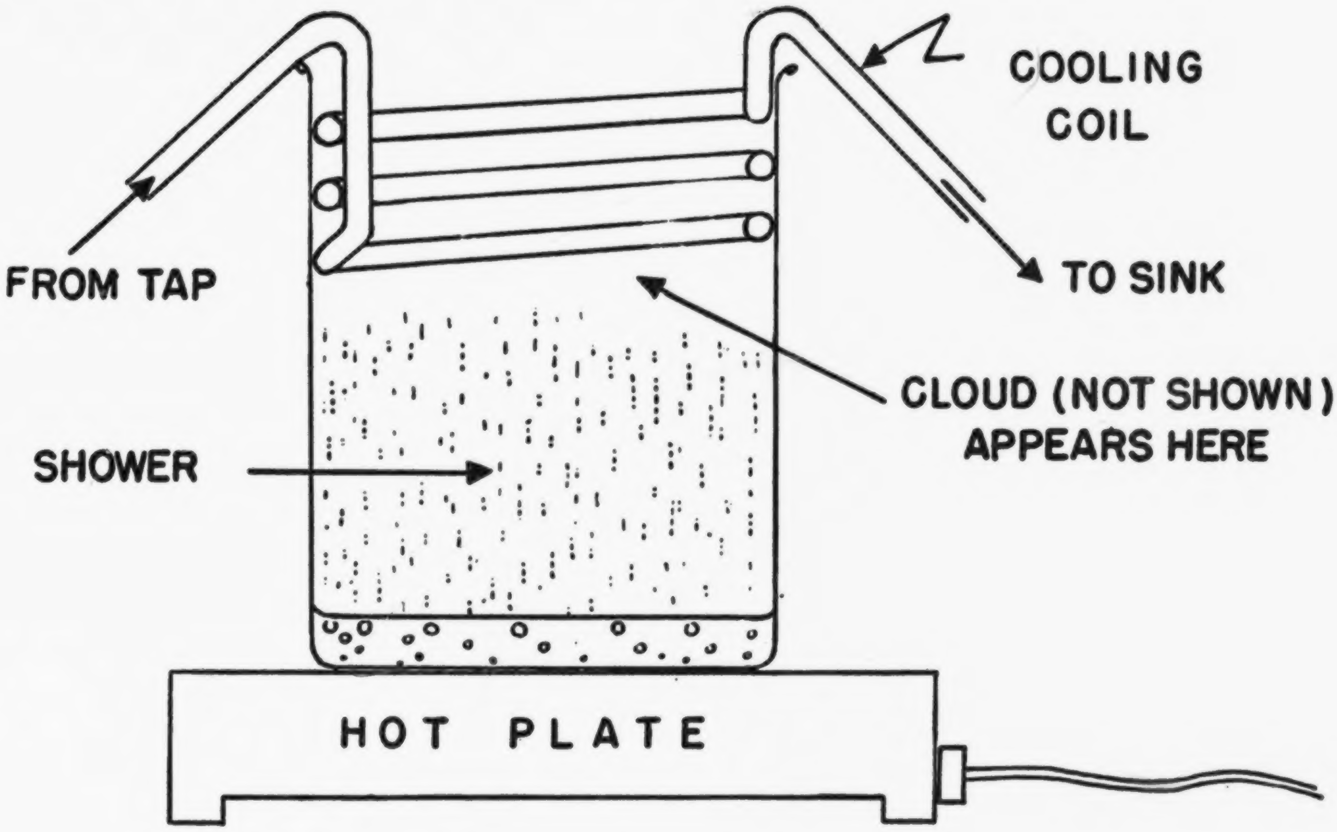
Insert the stopper firmly and repeat the experiment. If tobacco smoke from the mouth is used, it is interesting to notice how this very largely disappears as the compression continues. The class can usefully be guided to note and explain this. Finally, the stopper is blown out as before, but a very much thicker mist or fog is the result.

Principle involved: The abundant provision of nuclei for condensation and the frequency of occurrence of a larger particle in the precipitation results in the more impenetrable fog.

Cloud and Rain. Make a coil of two or three turns of narrow gauge copper or lead tubing (say, one-eighth-inch internal diameter) of such size that it will just fit into a large beaker and rest at the top. Connect one end of this coil to the tap and allow the other end to communicate with the sink. Pour a half-inch depth of trichlorethylene into the beaker, and set the latter up over on a hot plate or over a burner. Turn on the water so that the cooling coil can fulfill its purpose.

The following phenomena will be noticed. When the liquid begins to boil, or even before, a cloud formation with a very level base occurs above it and steadily rises. (This stage is transitory and should be sought carefully. It may be disturbed by draughty conditions, etc.) Soon there is a very manifest cloud around the cooling coil. It will now be noticed that a miniature shower of rain is falling from this cloud into the liquid. This continues. Disregard in observation of the "rain" any large drops of "dew" which fall from the coil itself. If it fits close to the sides of the beaker, the nuisance is minimized as the "dew" tends by surface tension to run down the latter.

There is little loss of liquid. The vapor is very heavy, and not much passes the cooling coils. Trichlorethylene is not inflammable, but it is anaesthetic and poisonous. One would not encourage the student to inhale from the beaker. Performed



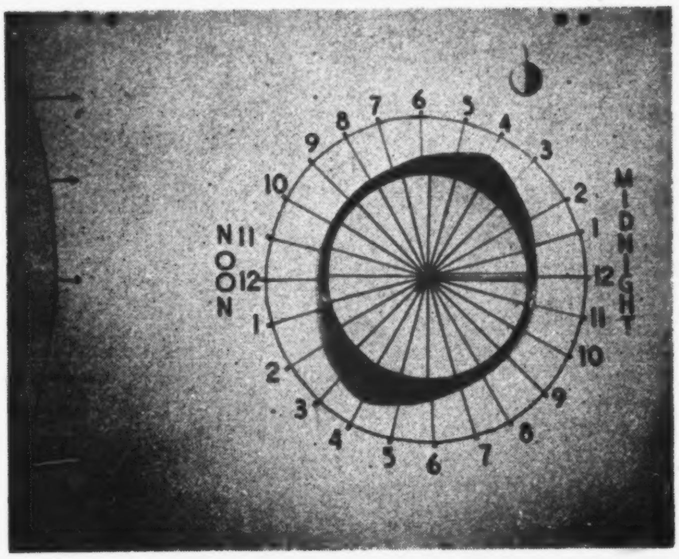
as indicated, there is no danger in the ordinary laboratory. The teacher in setting up this experiment for private trial should avoid smoking. Trichlorethylene passing through burning tobacco breaks down into a number of products, one being *phosgene* or carbonyl chloride which is deadly.

For various reasons trichlorethylene is a wonderfully effective liquid to use in this demonstration, but, if it is not available, kerosene will give a useful result. Kerosene, however, is inflammable, so it is necessary to make suitable modifications in method. For instance, remove the flame when the liquid is nearly boiling, or heat it over a large water bath.

Physics Test given at the beginning of the experiment. During the experiment, 15 short objective tests were given the experimental groups. The control groups took the teachers' conventional tests. At the close of the experiment a second *Cooperative Physics Test* was given to determine the gain made by each group. Tabulations of these scores and of the gains were made.

Conclusion. Houston high school Physics II students made a significant gain in factual physics information when given short frequent objective tests.

Recommendation. As a result of the findings in this study, it is recommended that short frequent objective tests be given Physics II students. It is to be remembered, however, that the only educational objective here considered is gain in factual information.



Tides and Times

RICHARD H. BRIDGMAN

Principal, Van Buren Junior High School, Kettering, Ohio

(SEPTEMBER 1952)

Each year when we study tidal movements and time zones I find it is difficult for the students to do the abstract thinking necessary for keeping in mind all the movements and positions of the sun, moon, and earth.

This year, while talking to a girl who had chosen this subject for a report to the class, I conceived a teaching aid that proved highly successful.

Four pieces of cardboard cut to the following sizes comprise the main materials:

1. 22 inches by 30 inches.
2. Egg-shaped piece 10 inches at the longest point and 8 inches at the narrowest point.
3. Circle of cardboard 7 inches in diameter.
4. Circle of cardboard 1½ inches in diameter.

On piece one a segment of the sun was drawn on the left and a circle 12 inches in diameter was drawn on the right. Since time stands still the hours of the day can be numbered around this 12-inch circle with 12 noon and 12 midnight perpendicular to the sun and in their correct relative positions.

Using part 3 as the earth and part 2 as the tides, mount these two parts in the center of the circle drawn on part 1. Use a small bolt to do this so parts 2 and 3 can be independently rotated.

Fashion a hook out of copper wire and use it to hang part 4 in any one of twenty-eight holes punched in part 1 and spaced evenly around the 12-inch circle on this piece. Part 4 represents the moon and can be placed in a position where we might find the moon and any one of its twenty-eight days during its journey around the earth.

It now becomes a relatively easy job to show the relationships between the sun, earth, moon, and tides.

In use I found 24 radius lines drawn on part 3, the earth, to correspond to the 24 time zones on the earth were of value in figuring the gaining or losing of time. I also found that if one of these twenty-four lines was made triple and the opposite radius line double and these were allowed to represent the international date line and zero degrees longitude, that it was much easier to explain the start of a new day and the gaining and losing of a day that may result when we cross the international date line.

To Show the Change of Seasons

VERNA SHIELDS and A. E. CLYDE

Pennsylvania University, University Park, Pennsylvania

(OCTOBER 1955)

Equipment

⅜″ x 3′ x 2′ Plywood
4 Red and Blue Rubber Balls
4 Knitting Needles
Pasteboard 1″ x 7″
½″ Mesh Hardware Cloth 6″ x 10″
¼″ Fibre Board
Protractor
Light bulb, socket, and cord

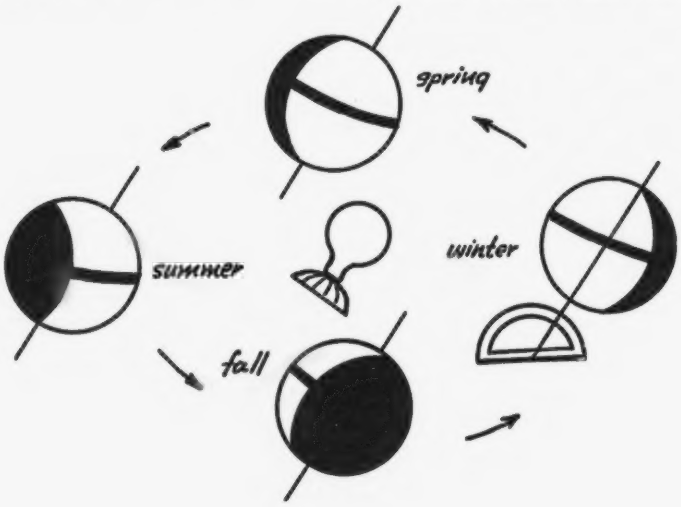


Figure 1

Instructions

The equipment is assembled on the plywood base in the conventional manner as shown in Fig. 1. A protractor is added as shown in Fig. 2 which helps to explain the expression, "the inclination of the earth's axis to the plane of its orbit."

From the fibre board a circular piece 1½″ greater in diameter than that of one of the balls is cut. A hole is cut in the center of the fibre board slightly smaller than the ball. The ball is then inserted into this hole. This is shown in Fig. 3 as representing the earth's atmosphere, and shows that rays from the sun must travel varying distances depending upon the earth's inclination.

The varying slant of the sun's rays is shown by using a piece of ½″ mesh hardware cloth cut to the shape of the ball (Fig.4). We allow each ½″ to represent a ray of light. This shows the amount of surface each ray would have to heat or light.

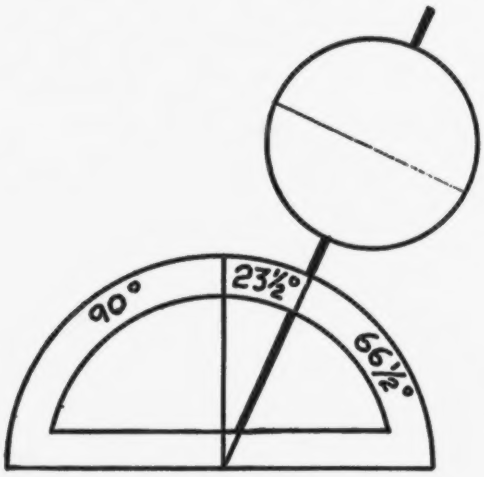


Figure 2

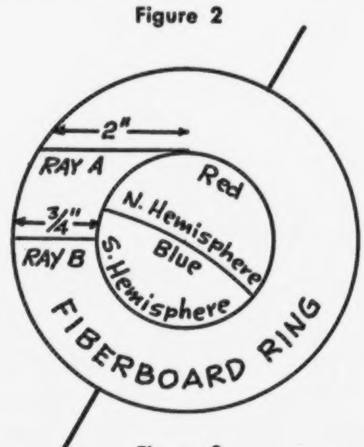


Figure 3

Distance traveled by Ray A through the atmosphere is over twice that of Ray B.

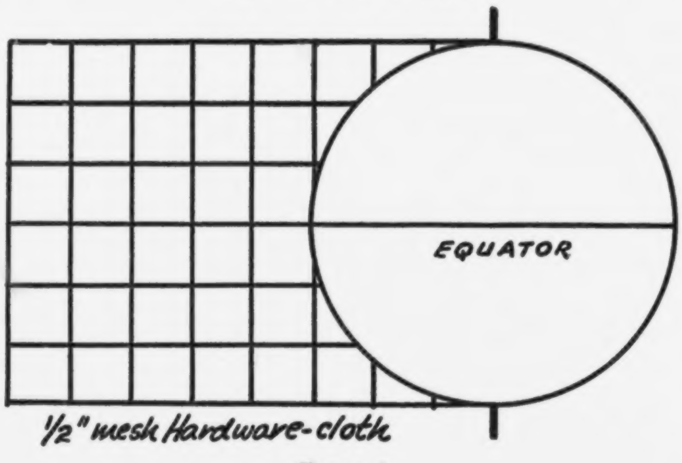


Figure 4

Longitude, Time, and Date

LELAND L. WILSON

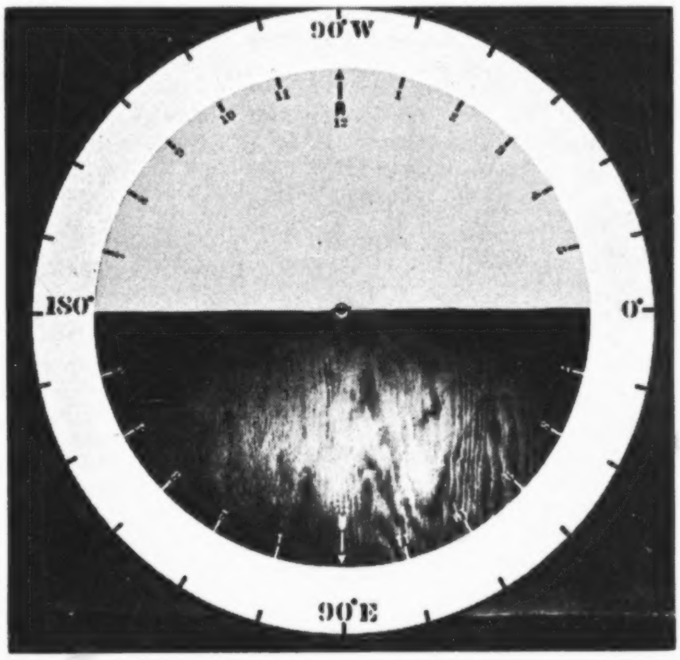
Professor of Chemistry, State College of Iowa, Cedar Falls, Iowa

(NOVEMBER 1956)

The relationship between longitude, time, and the date is often confusing to students encountering the subject for the first time. Textbook discussions of the topic explain that for westward travel the clock must be set back one hour for each 15 degrees of longitude and the calendar must be advanced one day on crossing the 180th meridian. Students often fail to realize that the calendar is set back a day at the point where the time is 12:00 midnight. These relationships are not easy to visualize since time undergoes continuous change and, as the point of midnight moves west, the part of the earth having a given date also changes continuously. The apparatus pictured here enables the student to clearly see the relationship between the longitude, time, and date.

The device consists of two large plywood disks. The larger one indicates longitude and each mark corresponds to the *center* of a time zone 15 degrees wide. The smaller disk indicates time with the daylight hours on the white half and the hours of darkness on the black half. The small disk is mounted on a bolt at the center so that it will turn and can be set at any position by tightening a wing nut.

Given the time and date at any longitude, one can determine the time and date for any other longitude at a glance. For example, one can see from the setting of the apparatus in the picture that if it is 12:00 noon on October 10 at 90 degrees W. longitude, it is 7:00 P. M. on October 10 at 15 degrees E. longitude and is 3:00 A. M. on October 11 at 135 degrees E. longitude. As the smaller disk is rotated counterclockwise, corresponding to the rotation of the earth, one can see the portion of the earth having the date October 10 getting smaller and that portion having the date October 11 getting larger. A few minutes practice with this apparatus will give the student a clear understanding of this problem and will eliminate the necessity for laborious blackboard diagrams.



Coriolis Force

JOHN LYMAN

Program Director for Oceanography, Earth Sciences Section, National Science Foundation, Washington, D. C.

(APRIL 1961)

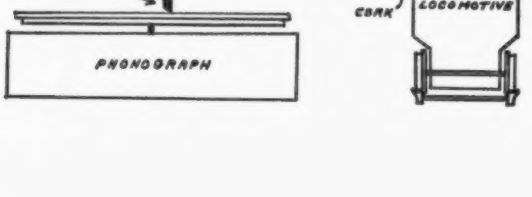
NEWTON'S LAWS OF MOTION, applied to the graphic information derived by combining some readily available household articles, can be made to yield both a convincing demonstration of the reality of *Coriolis Force* and a quantitative basis for deriving a formula for it.

The following materials are needed:

1. An electric train. I used an S-gauge train, but an O-gauge or especially an 027-gauge would be even better in view of the smaller table top required to make a circle. An HO-gauge train is probably too delicate for the operation. Any of these trains will have speed control through transformer and a locomotive that is readily reversible. Only the locomotive and transformer are needed, with enough track to make an oval having two or three straight sections.
2. A three- or four-speed phonograph. It must have a tone arm that can be retracted far enough to permit an outrigger from the train to sweep as far as the middle of the turntable without interference.
3. A supply of corrugated cardboard sheets, cut to the size of a 12-inch phonograph record.
4. A couple of felt-tipped marking pens ("Magic Marker," "Draws-a-Lot," etc.) in contrasting colors.
5. A pair of small corks, a wire coat hanger, Scotch tape, a knife, and pliers.

Trim the corks so that they will fit snugly into opposite windows of the locomotive cab. From the coat hanger, fashion a piece of wire with an eye in one end to hold one of the marking pens and a straight length sufficiently long to reach through the locomotive cab and past the center of the phonograph turntable. Secure this wire to the locomotive by passing it through the corks, as shown in Figure 1.

FIGURE 1.



Now, position the phonograph next to a straight portion of the track. Adjust the height of the phonograph (pieces of the corrugated cardboard under it are useful for fine adjustment) and the curvature of the outrigger wire until the locomotive will carry the pen in such a way as to make a neat straight line across a piece of the cardboard on the motionless phonograph turntable.

You are now ready to start taking data. I found it useful to call for some volunteer geophysicists from the class—a qualified operating engineer to run the transformer, a musician to operate the phonograph, and a display artist to hang the cardboard discs as they are produced on the top of the blackboard with Scotch tape. The badge of authority, the second marking pen, is retained by the instructor to add annotations of speed and rpm to the records along with an arrow indicating the direction of motion of the pen.

Two primary data series should be taken with this equipment. First, holding the train speed constant as it goes through the straight stretch, vary the turntable speed from 78 down to 16⅔ rpm. Instead of the straight line that it drew when the turntable was motionless, the pen now draws a series of curves like those in Figure 2(a).

Then, with a moderate rate of rotation, take a second series with train speed as the variable. Results will look like Figure 2(b), and the spectrum of speed can be expanded by reversing the direction of the train.

It is not possible to reverse the direction of rotation of an AC phonograph (unless there happens to be a belt drive, in which case the belt can be varied between a figure-eight and an oval); but a DC phonograph can be reversed by reversing the leads from the batteries. In the absence of either of these means of obtaining an actual record during counter-clockwise rotation of the turntable, the class can be asked to consider what would happen if the pen arm were arranged so as to permit two pens to mark both sides of the turntable simultaneously.

It is clear that in this event the trace on the lower side would be the mirror image of the upper trace, *i.e.*, the deflection would be to the right of the direction of movement of the pen, instead of to the left as it invariably is when the turntable rotates in its normal clockwise direction. Viewed from the lower side, the turntable has counter-clockwise rotation, just as the Earth has when viewed from the Northern Hemisphere.

The rotating turntable is thus a model of our Earth—flattened at the poles much more than in nature—and its clockwise rotation corresponds to the Southern Hemisphere. The straight train tracks, and therefore the motion of the pen which they constrain, correspond to particle trajectories fixed with respect to the stars and independent of the coordinates of the rotating earth. But on this earth such a straight trajectory becomes a complex curve, with deflection always to the left of the direction of motion in the Southern Hemisphere and to the right in the Northern.

We can now introduce Newton's Laws of Motion. The First Law states that any body persists in a state of rest or of uniform motion in a straight line unless a force is imposed to change that state. But we have just found that the motion of the pen over the turntable is a straight line only if the turntable is not turning. As soon as there is any angular rotation of the turntable, the motion of the pen relative to it is in a curved path. Therefore, introduction of angular rotation to the turntable also introduces a force that causes the pen to make a curved trace.

How great is this force? We can answer this question through application of the Third Law of Motion which tells us that for any action there is an equal and opposite reaction. Although the pen traces a rather complex curve, any short portion of it can be represented with reasonable precision by a circle of appropriate radius. A body of unit mass moving in a circle of radius r at speed v is acted upon by a centrifugal force away from the center equal to v^2/r. The force toward the center that we are seeking is also v^2/r.

What have we learned about the variation of r? The results of Figure 2(a) show at once that r varies inversely with angular velocity ω and Figure 2(b) shows that r is proportional to speed v. It is clear also that we have the greatest curvature (smallest r) at the axis of the turntable. That is considering the spheroidal earth, r is smallest at the poles. It does not become infinitesimally small, however, as the curvature of the trace varies smoothly if the pen passes directly over the axis, and it does not show a cusp. In a similar manner, since we have already deduced that our force changes from right-handed force in the Northern Hemisphere to the left-handed in the Southern Hemisphere, it follows that the force must vanish at the Equator. No curvature of a path exists at the Equator, which is the same as saying that the Equator has infinite radius of curvature. The cosecant of the latitude (ϕ) meets the specification of a quantity that varies from infinity at the Equator to a minimum but finite value at the Pole.

We have thus established that r is directly proportional to v and $\csc \phi$ and inversely proportional to ω; or introducing a constant of proportionality k, we can write

$$r = kv \csc \phi/\omega.$$

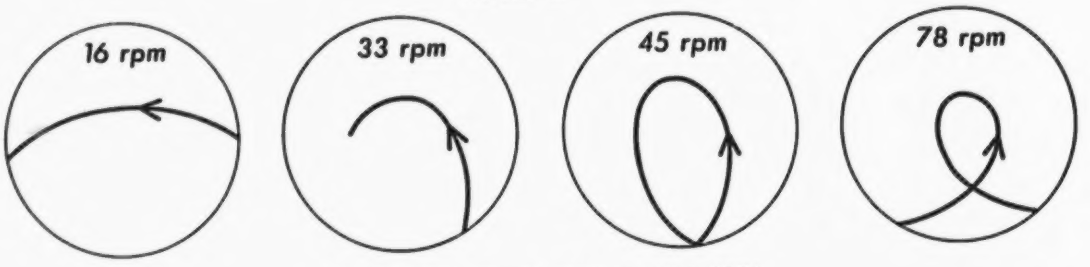
Substituting this expression for r in the relationship for the deflecting force of the Earth's rotation that we previously deduced, we have for unit mass:

$$\text{Deflecting Force} = v^2/r = \omega v/k \csc \phi = \omega v \sin \phi/k$$

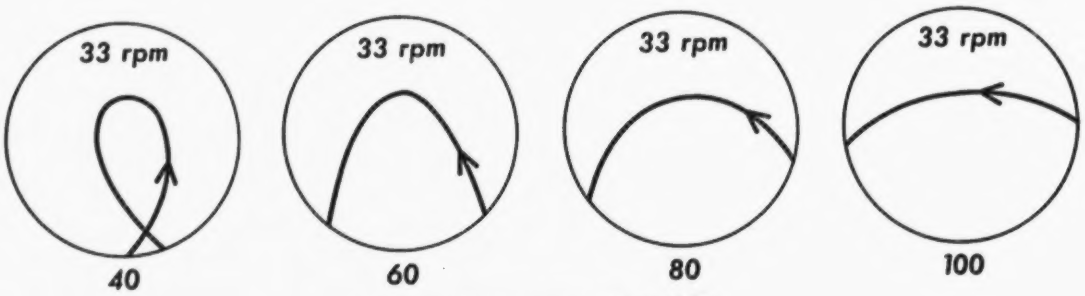
The constant k as here written turns out to have the value of ½, and this expression thus becomes identical with the equation for Coriolis Force:

$$F = 2\omega v \sin \phi.$$

FIGURE 2.



(a) TRAIN SPEED CONSTANT (50)



(b) TRAIN SPEED VARIABLE

A Tin Can Planetarium

FLETCHER G. WATSON

Professor of Education, Harvard University, Cambridge, Massachusetts

(NOVEMBER 1950)

A "TIN CAN" planetarium, a simple device for projecting star images, can be made by following the instructions below. With this device children can learn, under a teacher's supervision, to identify the brighter stars and the more obvious constellation groups. With such a start and a star map they can, at home or elsewhere, go on to learn the other constellations, if they desire.

This "planetarium" shows only about 125 of the brighter stars. Stars fainter than the third magnitude are not shown, except when necessary to complete a few conspicuous patterns, because street lights obliterate fainter stars for most city dwellers. Even where faint stars can be seen, first familiarity with the heavens should be limited to a few bright and conspicuous groups.

The finished instrument consists merely of a flashlight bulb shining at the center of a surrounding can. Through small holes in the can the light of this bulb goes out to strike the walls of the surrounding room and to form on the walls small images of the bulb's filament resembling stars. The lamp filament should be as small as possible, and the holes should also be small and properly located.

Just as the positions of all places on the earth are recorded in latitude and longitude, the positions of all heavenly bodies are determined in a similar set of coordinates. One coordinate, similar to latitude and known as "declination," is measured both northward and southward from the celestial equator towards the poles. The other coordinate, similar to longitude and known as "right ascension," is measured only eastward from an arbitrary point (the Vernal Equinox). To plot the stars on the can we need to lay out on it a coordinate system, north-south and east-west, equivalent to the coordinate system used on a spherical sky.

Once the positions of the stars have been plotted, small holes can be punched in the can with a conical punch, like a phonograph needle. Bright stars are represented by relatively large holes and faint stars by very small holes.

Procedure

Select a clean can of size number 2 or larger, up to one gallon. Give the outside and top a coating of thin white or cream paint. This will provide a base on which to draw the coordinate grid used when plotting the star positions. Give the inside of the can a coating of dull black paint; this is to eliminate internal reflections which produce multiple images of the stars.

Determine the diameter and height of the can and carefully draw on a sheet of paper the outline of a central cross-section as in figure 1. Draw the central axis of the can; the "north pole" is to be where this central axis goes through the top of the can. Along the central axis measure down from the top a distance of three-fourths of the can's diameter (this distance is not critical, but should not exceed one full diameter). This point on the central axis is the "center of projection"; in the finished model this is the point to be occupied by the filament of the bulb.

Through the center of projection draw a horizontal line which marks the "equator." Around the center of projection draw a circle, having the same radius as the can, to represent the celestial sphere. With a protractor mark off along this circle ten-degree intervals, both north and south from the equator. With a straight-edge draw lines from the center of projection through each of the ten-degree

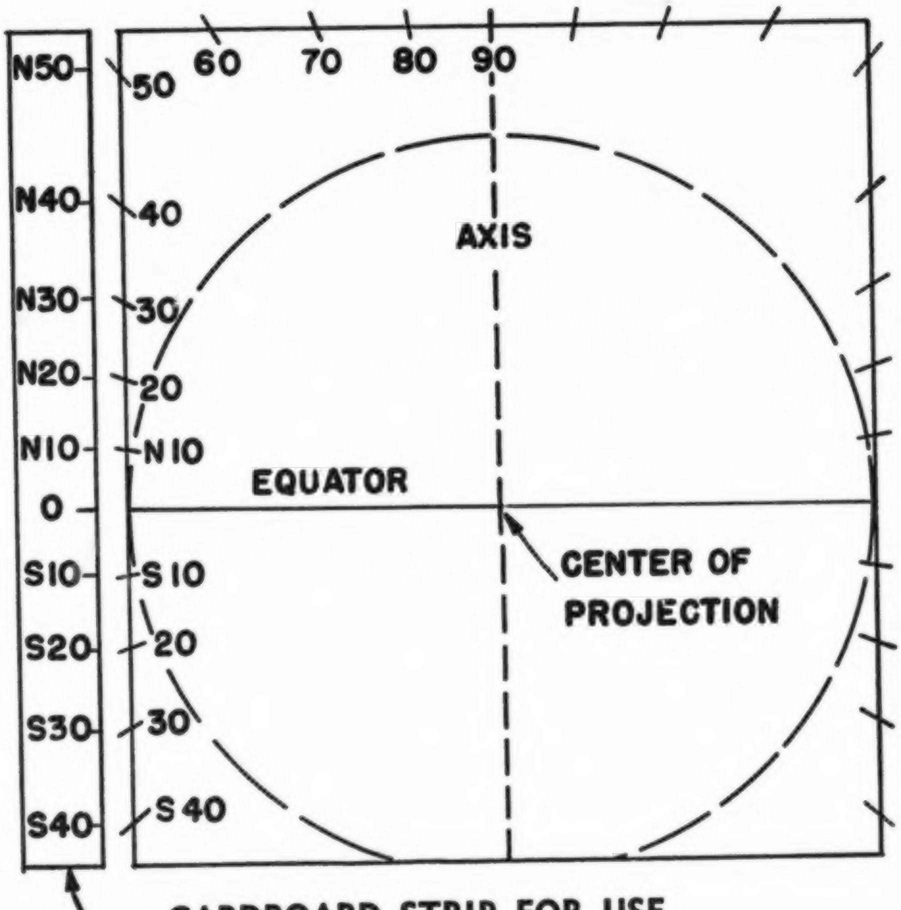


FIGURE 1. How to establish the north-south scale

CARDBOARD STRIP FOR USE IN TRANSFERRING SCALE TO SIDE OF CAN

points until the lines cut the outline of the can. Label northward the points along the can outline from 0° from the equator, 10°, 20° . . . up to the central axis which is 90°—the north pole. From the equator, also number down as far as you can go; this should be to 40° or 50° south. The north-south, or declination, scale is now established and is ready to be transferred to the can. This is readily done by copying the scale on a strip of cardboard which may be held against the can for marking. A similar strip may be used to transfer the north-south scale to the top of the can where circles are drawn as in figure 2. Incidentally, the north-south scale on the side of the can is a "cylindrical projection" which resembles but differs from a Mercator projection used for many maps.

The "around" or right ascension scale is more easily made. Trace around the can, as in figure 2, and locate the center of this circle. Draw one diameter; from it mark off with a protractor each 10° interval up to 360°. This around-scale for the top of the can may be cut out with scissors and laid over the actual can so the ten-degree marks can be transferred to the rim. With a straight-edge draw the diameters across the can until the top is a "pie" of 36 pieces each 10° wide. When looking down on the top, label the ends of these radii from 0° to 360° proceeding *counterclockwise*. From these points on the top rim draw straight, equidistant lines down the sides of the can to the bottom, parallel to the seam on which the can was

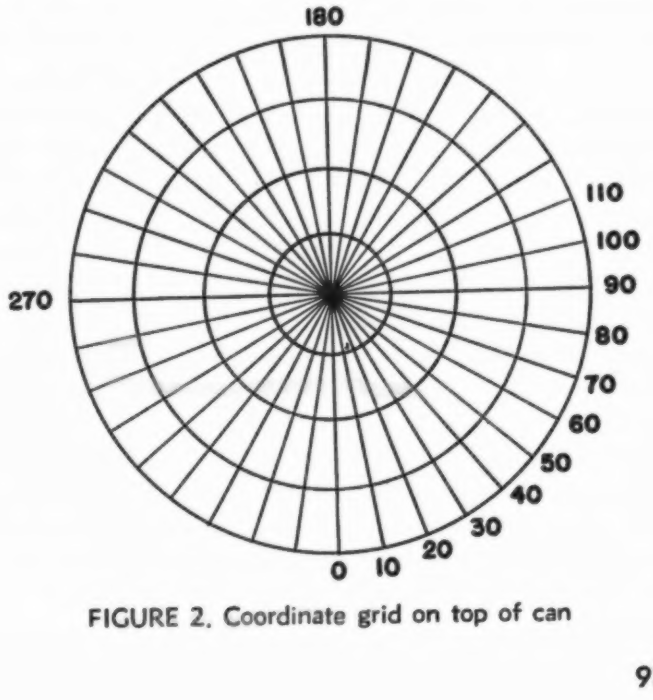


FIGURE 2. Coordinate grid on top of can

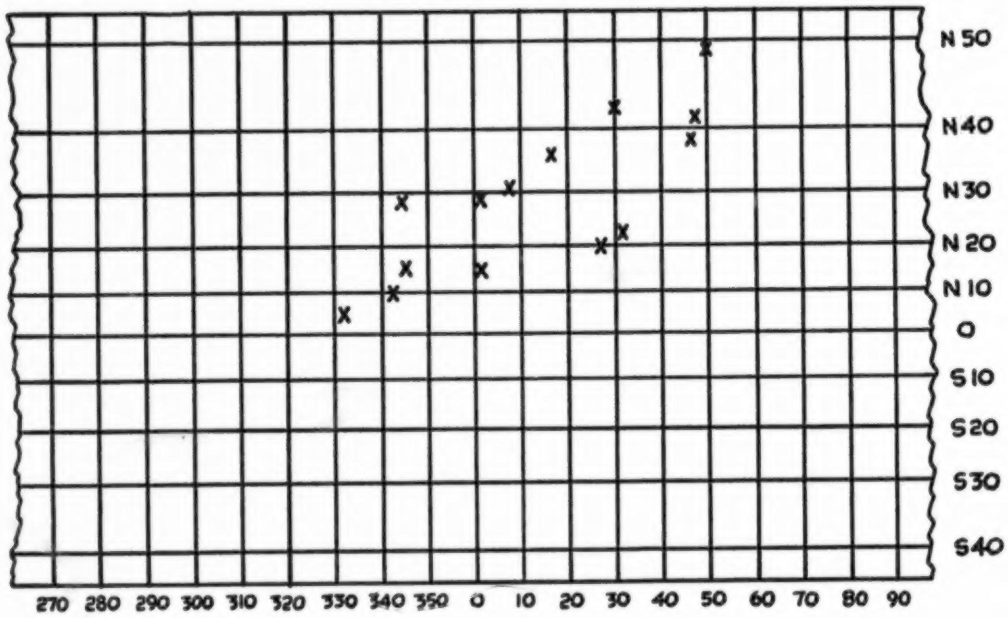


FIGURE 3. Side view of can, as though flattened out

welded. Then, if we imagine the side of the can unrolled, we would have a sheet of graph paper as in figure 3.

The star positions to the nearest degree are listed in the table (p. 183) according to the two coordinates: right ascension (RA) or "aroundness," and declination (D) or "north-southness." The stars are grouped by constellations, and the brighter stars are named. These star positions should be plotted carefully with a pencil and checked before any holes are punched in the can. Remember, right ascension is measured *counterclockwise.* In the table the brightness of the stars is indicated by B (bright) for those of magnitude zero or one, M (medium) for those of second magnitude, and F (faint) or FF (very faint) for those of third or fourth magnitude.

The holes in the can should be punched with a sharp, conical tool; a phonograph needle has proved satisfactory. For the fainter stars the smallest hole possible should be made. Slightly larger holes for the brighter stars can be made by hitting the punch harder. If the holes are too large, the illusion of stars is poor. Before punching at the plotted positions, some practice on another can is advisable.

The Light: The light source should be a plain (non-focusing) flashlight bulb. Furthermore, it should have as small a filament as can be obtained. The socket holding the bulb should be adjusted to bring the filament into the plane of the equator. Sockets from Christmas-tree lights have been satisfactory. The bulb should be operated on its rated voltage or slightly higher. A bulb rated at 2.5 volts operated on two "standard" flashlight batteries works well. Two small angle-irons form a satisfactory spring holder for the batteries.

The Mounting: The mounting should have a wide base to prevent tipping over. Two up-rights, as in figure 4, support on two screws the platform which holds the light socket and the base of the can. A few long finishing-nails in this platform around the can will support it and still allow it to be rotated—clockwise—by hand. The platform, mounted in this manner, can be tipped to present the stars as seen from the north pole (vertical) to latitudes down to around 40° N.

The position of the sun among the stars on a given date and its annual eastward motion among the stars, as well as the seasonal effect (north to south to north), can be represented by a flashlight held over the can and properly pointed. Individual ingenuity will probably suggest additional celestial phenomena that can be represented.

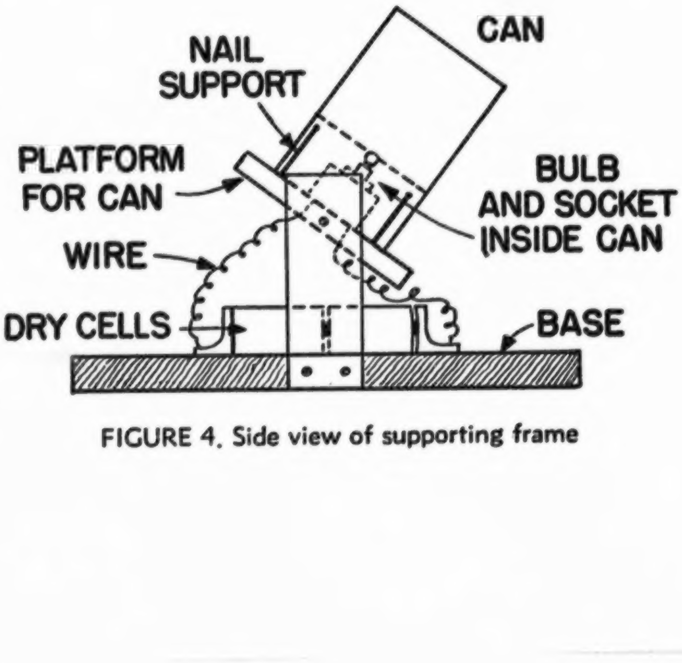


FIGURE 4. Side view of supporting frame

Table of Star Positions

Dec.	R.A.	Br.	Name
Ursa Minor			
N89°	020°	m	Polaris
N72	230	f	
N75	222½	m	
Ursa Major			
N62	165	m	> Pointers
N57	164	m	
N54	177	m	
N57½	182½	f	
N56	192½	m	
N55	200	m	
N50	204	m	
Cassiopeia			
N59	001	m	
N56	009	m	
N60	014	m	
N60	020	f	
N63	027½	f	
Andromeda			
N29	001	m	
N30	009	f	
N35	017	m	
N42	030	m	
Aries			
N23	031	m	
N20	027½	f	
Cetus			
S19	010	m	
Perseus			
N49	050	m	
N41	046	m	Algol
N39	045	f	
Taurus			
N24	055½	ff	Pleiades
N16	068½	b	Aldebaren
N15	064	f	
N18	065	f	Hyades
N19	066	f	
N28	080	m	
N21	083½	f	
Auriga			
N46	078	b	Capella
N45	088½	m	
N38	088½	f	
N33	073½	f	
N41	075	f	
Orion			
N7½°	088°	b	Betelgeuse
N6	080	m	
N10	082½	f	
Zero	082	m	
S1	083	m	
S2	084	m	
S9	077½	b	Rigel
S10	086	m	
Gemini			
N32	113	b	Castor
N28	115	b	Pollux
N17	098½	m	
N22½	095	f	
Canis Major			
S17	100½	b	Sirius
S18	094½	m	
S26	107	m	
S29	104	m	
S29	110	m	
Canis Minor			
N5	114	b	Procyon
N9	110½	f	
Hydra			
S9	141	m	
Leo			
N12	151	b	Regulus
N17	150½	f	
N20	154	m	
N24	153	f	
N24	145	f	
N21	167½	m	
N16	167	f	
N15	176	m	Denebola
Virgo			
S11	200	b	Spica
Bootes			
N20	213	b	Arcturus
N27½	220½	m	
N34	228	f	
N41	225	f	
N39	217½	f	
N30½	217½	f	
Corona Borealis			
N31½	232½	f	
N29	228½	f	
N27	233	m	
N27	235	f	
N27½	239	f	
Hercules			
N39°	250°	f	
N31	249½	f	
N21	247½	f	
N37	258	f	
N31	254½	ff	
N25	258	f	
Ophiuchus			
N12	263	m	
Scorpio			
S20	240	m	
S22½	239	m	
S26	239	f	
S25	244	m	
S26	246	b	Antares
S28	248	f	
S34	251	m	
S38	251½	f	
S42	252½	f	
S43	257	f	
S43	263	m	
S40	265½	f	
S39	264½	m	
S37	262½	m	
Lyra			
N39	279	b	Vega
N38	280½	ff	
N37	283	ff	
N33	282½	f	
N32	284	f	
Cygnus			
N45	310	b	Deneb
N40	305	m	
N45	295½	f	
N35	298½	ff	
N28	292½	f	
N34	310½	m	
Aquila			
N10	295½	f	
N9	297	b	Altair
N7	298	f	
Pegasus			
N10	325	m	
N6	332	f	
N10	342	f	
N15	345	m	
N28	345	m	
N15	002	m	
S30	344	b	Fomalhaut

Constellations With "Tinker Toys"

EDWARD G. HALDMAN

Science Instructor, Salem High School, Salem, New Jersey

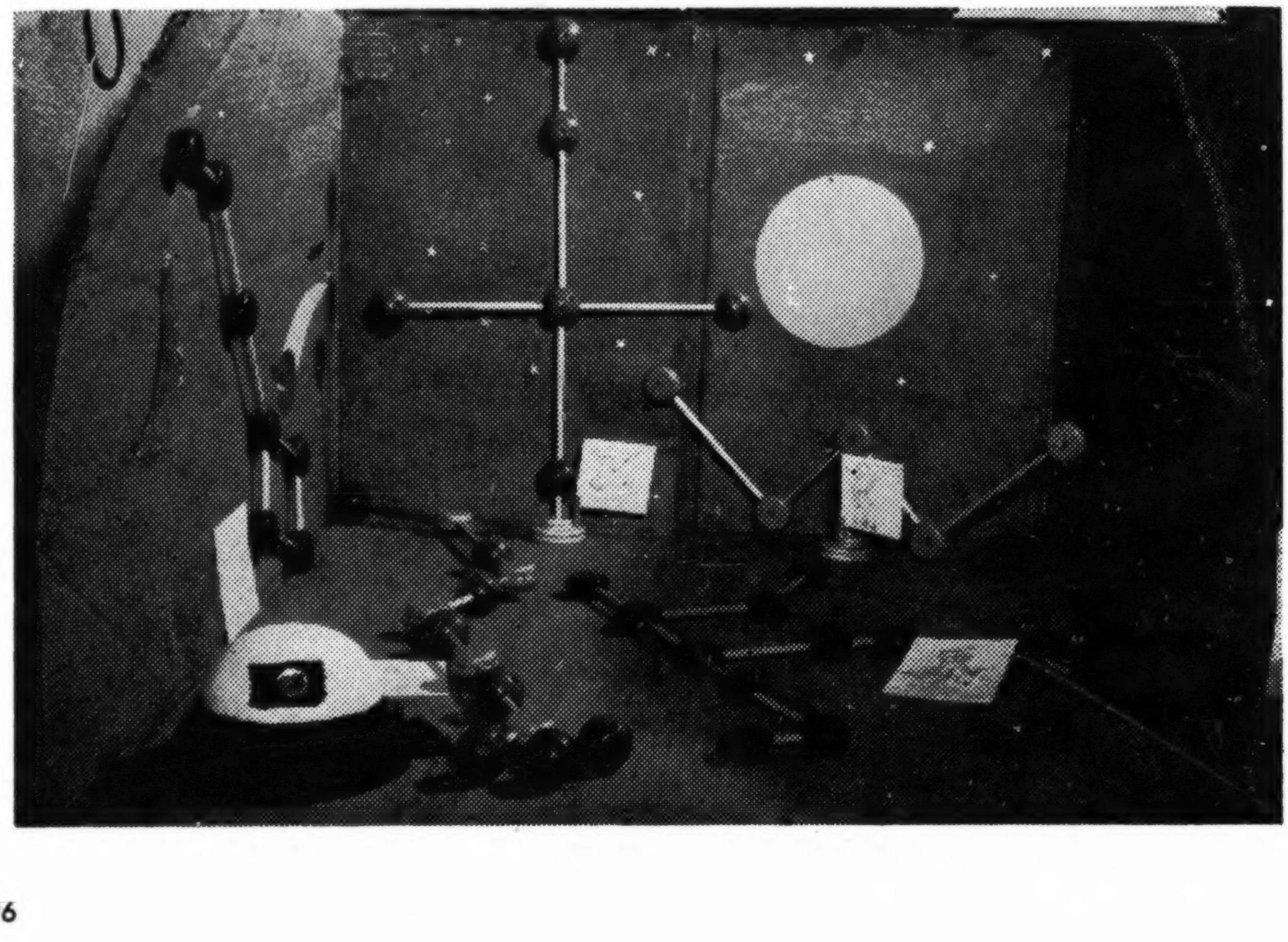
(MARCH 1952)

Here is an exhibit which has fired the imagination of many children in elementary science. It is a project which is not only educational but also provides entertainment.

Almost any home which has adolescents in it also has a set of construction toys, more commonly called "Tinker Toys." From the picture you can see that the children have housed the exhibit in a cardboard box and have painted it blue to represent space. To make it more representative of space they have added silver stars, a red sun, and an aluminum foil moon. With this as a start they found constellation maps and from these made the simpler and more familiar constellations. They used the sockets as stars and the sticks as connecting links. There are Draco—the Dragon, Casseopeia—the Woman in the Chair, Hercules—the Strong Man, Ursa Major—the Big Bear or Dipper, and Cygnus—the Swan. The observatory in the lower left of the picture was made out of wood as the personal project of one student.

Many students enjoyed making constellations in their own living rooms, and they went out to locate them in the heavens. This project also stimulated their interest in the stories of the ancient Greeks and acted as a motivating force in learning.

Some students developed their artistic abilities by drawing the identification cards. By using projects of this sort astronomy has become one of the favorite topics in our elementary science program. Try it for yourself, and see its amazing results.



A Ceiling Solar System

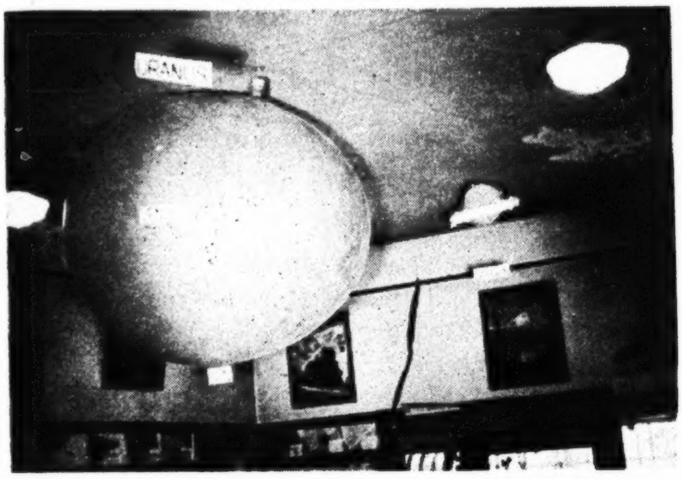
ALBERT PILTZ

Specialist, Science Instructional Equipment, U. S. Office of Education, Washington, D. C.

(SEPTEMBER 1952)

A CEILING solar system was first conceived by the writer in 1948 at the Roosevelt Elementary School, Detroit, Michigan. A practical model was developed that same year with a group of sixth grade children. These children were motivated through a unit study of stars and planets.

The amount of detailed information and resourcefulness necessary for the construction of this system afforded the children extensive learning experiences.



These children maintained an unusually high level of interest in the solar system throughout their grade school years. Each succeeding group of children, upon entering the classroom, would look up at the ceiling, see the sun and the nine planets—the family of celestial bodies to which our earth belongs—as though they were viewing them from a distance from far out in space. The effect brought immediate response. The dramatic arrangement of planets and sun created a feeling which inspired even the youngest to ask almost endless numbers of questions.

Many elementary teachers have since used the idea of their classroom situations with equal success. Some teachers have modified the plan to fit special situations. A ceiling solar system was reconstructed last summer by in-service teachers in a Science Workshop, University of Florida. They further checked its function, utility, and effectiveness. It met with great favor by the group.

Construction:

A ceiling solar system can be made simply and inexpensively by groups of children. The children can easily construct the nine planets by using wet strip paper and wheat paste and molding the paper into spherical shapes. The larger planets (Jupiter and Saturn) are made similarly. Balloons inflated to proper dimensions (see chart) are used as molds. Strips of paper are run through paste and pasted around the balloon. When the paper and paste dry, they harden and form the desired shape. This tends to lighten the weight of the larger planets and makes for permanency of shape. Cotton batting and wire may be used to construct Saturn's ring.

PLANET CHART

Planet Name	No. mil. mi. away from the sun	Twenty mil. mi. equals one inch on scale	Miles in diameter	Eight thousand mi. equals one scale inch
Mercury	36	1.8	3000	3/8
Venus	67	3.3	7600	19/20
Earth	93	4.6	7900	79/80
Mars	141	7.0	4200	21/40
Jupiter	449	24.5	87000	10 7/8
Saturn	886	44.3	72200	9
Uranus	1782	89.1	31000	3 7/8
Neptune	2793	139.6	33000	4 1/8
Pluto	3670	183.5		

The satellites can also be made of papier-mâché. A straight pin, pushed through the center of the satellite and fastened to the planet, is all that is needed to hold it in place. The number of satellites for each planet and their proportionate sizes may be found in any science text dealing with astronomy.

An army target balloon or a large weather balloon may be used to represent the "sun." The sun should be inflated to as great a diameter as possible. This may be done by using the blowing end of a vacuum cleaner. Although the sun when inflated appears very large, it is the only solar-planet size ratio that is inaccurate. It does, however, give the children a better idea as to relative differences in size of planets and sun. Discussion with the children will direct attention to these differences. At the same time, concepts of motion and velocity may be developed.

The sun may be painted with tempera, either red, orange or yellow. The planets may be done in dark blue and the satellites in bright yellow. Labels, naming the planets, may be suspended by thread and fastened to the planets by the use of scotch tape. These should be large enough for the children to see, and should be lettered on both sides.

Materials:

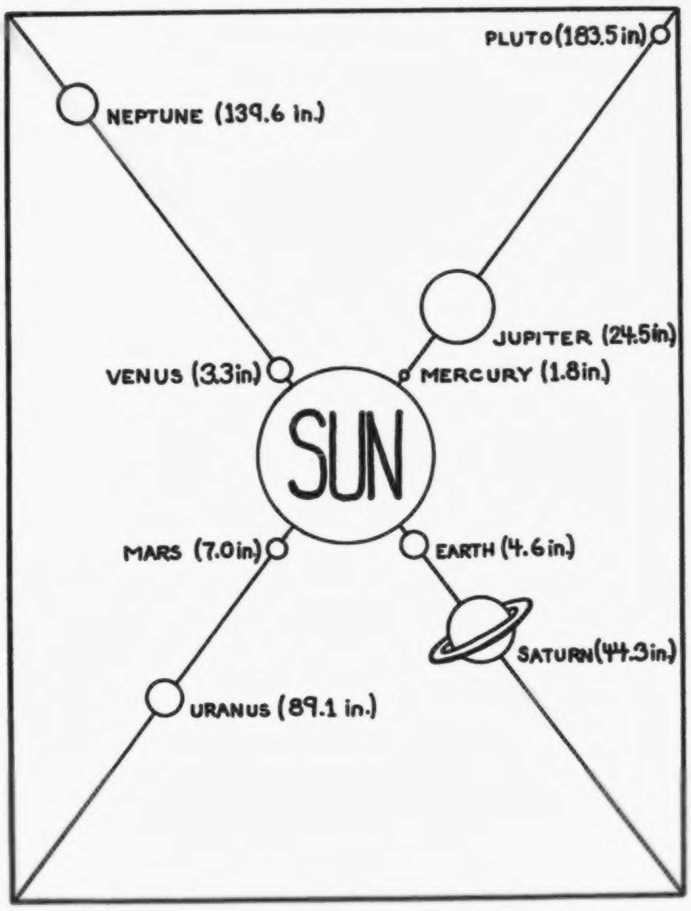
1 Army target balloon (surplus material) represents the sun
2 toy balloons (Jupiter and Saturn)
Cotton batting and wire (Saturn's ring)
Thread (labels)
Papier-mâché
Tempera paint
Wire (to suspend planets)

Method:

String wires diagonally across the classroom from corner to corner. Either fasten the wires at the top of light fixtures or on molding. At the point where all the wires cross, the middle, suspend the inflated target balloon. This represents the sun, the center of the solar system.

Use the previous chart for accurate diameters of the planets. Use the classroom plan drawing for accurate spacing of planets. This plan has been worked out to fit the average size classroom.

CEILING SOLAR SYSTEM



FLOOR PLAN - TYPICAL CLASSROOM
CEILING SCALE: 1 in = 20 MILLION MILES (approx.)
NUMBERS IN (·) ARE ACTUAL MEASUREMENTS FROM OUTER EDGE OF THE SUN ON CEILING

An Inexpensive Planetarium Dome

WILLIAM M. THWAITES

Walter Colton Junior High School, Monterey, California

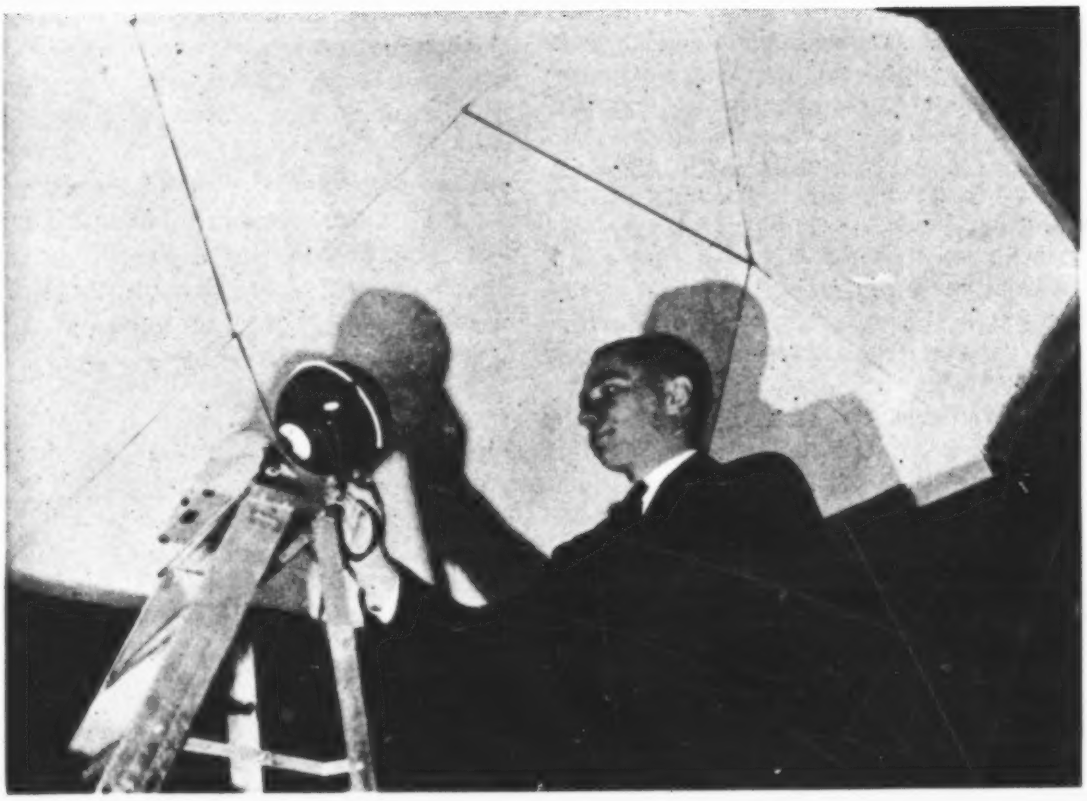
(MAY 1961)

A PLANETARIUM DOME can be built of corrugated cardboard at nominal cost and can be stored flatly during periods when not in use. This dome when used with a low cost commercially available star projector can provide an economical stimulus in the teaching of elementary astronomy.

The need for providing a stimulating experience in space science is made clear by daily newspaper headlines. A planetarium can provide a learning experience in some ways that surpass direct observation. Unfortunately few schools have been willing to put up with the expense and inconvenience of providing such an installation. Essentially any expense and many of the difficulties can be avoided with the combination suggested here.

The dome is intended for use with a low cost star projector available through toy stores, as well as through some scientific equipment companies. This projector cannot be used alone in a normal partially darkened classroom. A dome of some sort must be provided in order to make the star images clearly visible. In addition, the dome provides a realistic likeness to the celestial sphere observable in nature. (See Figure 1.)

FIGURE 1. The dome, nearly hemispherical, provides about 6.5 square meters of projection area.



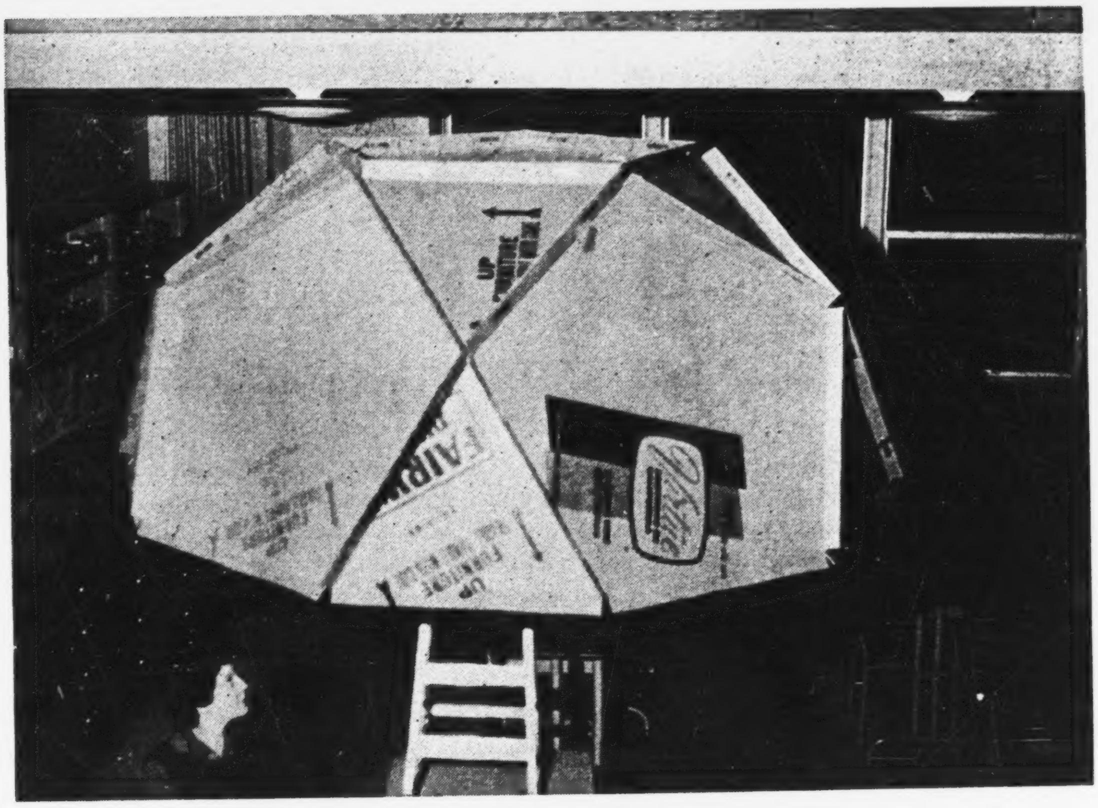


FIGURE 2. The structure incorporates ten triangles, makingit rigid and lightweight.

The structure pictured here is about two meters in diameter and easily accommodates fifteen students plus the teacher. It has a semi-regular polyhedral shape requiring the use of six pentagons and ten triangles, one-half of an icosidodecahedron. (See Figure 2.) Each face is regular with all sides measuring sixty-five centimeters. The faces were flanged and fastened with Acco No. 22 paper fasteners. The inside was painted with flat white paint to provide an optimum projecting surface and the entire structure was suspended by pulley from the ceiling. When the dome was not being used, it was quickly lifted out of the way. At the conclusion of the astronomy unit it was taken apart in a few minutes for storage.

This simple structure made it possible to demonstrate not only identification of star groups, but also diurnal motion of the stars, celestial poles, celestial equator, meridian, zenith, horizon, latitude determination, and other spacial concepts normally impossible to demonstrate. Expense and inconvenience should not be deterring factors in providing this space experience in our space age.

A Laboratory Activity in Astronomy

RICHARD H. LAMPKIN

Professor of Science, State Teachers College, Buffalo, New York

(APRIL 1954)

I am primarily concerned now with the preparation of teachers for elementary schools. Therefore, I am pleased and gratified to be asked to present a demonstration for experienced teachers at the junior high school level.

I have elected to present a laboratory activity in astronomy. It should be considered in the following frame of reference. We wish students to acquire certain concepts such as changes in the apparent place of the sun (through the hours, days and seasons), clock time and calendar time, the coordinate system using latitude and longitude, and how to measure the latitude and longitude of any place where we happen to be. All too often we merely look at pictures, or talk or read about such concepts. These are good, but possibly we can find other suitable teaching-learning activities. The apparatus presented here is only a development of the shadow stick which has been used in primary grades for many years. It has been used here to present some stories to be read in sunlight and shadows—some astronomical and geographical concepts. You, teachers of junior high school students, may use as much or as little of it as you think wise.

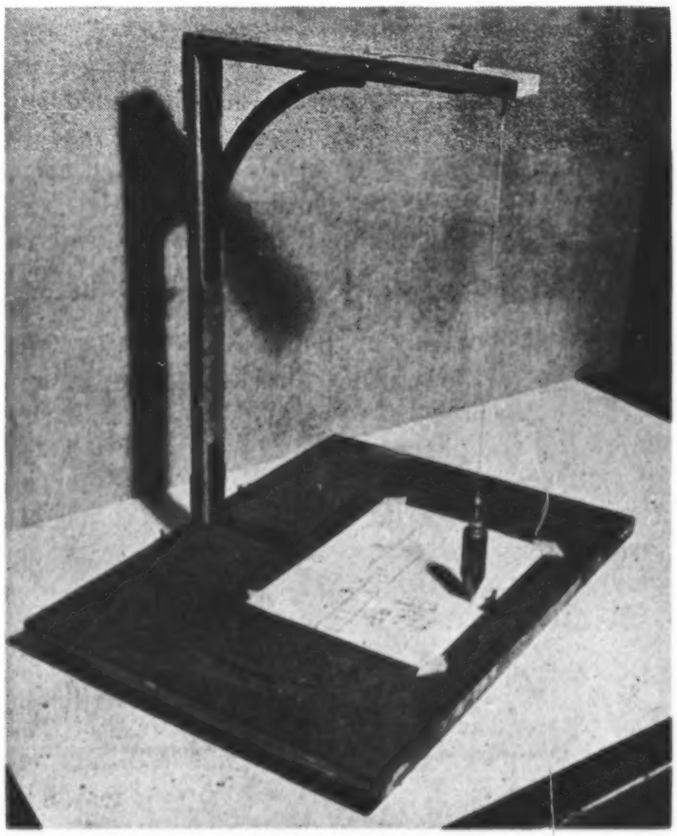


FIGURE 1

General view of apparatus. Wing nuts on the supporting brackets make it easy to take the apparatus apart for con-

Set up the apparatus as shown in Figure 1 where the sun can shine on it most of the day, with the plumb-line support on the north or shadow side of the base, and preferably shielded from the wind. Before making observations, level the baseboard by means of the leveling screws provided; the level vials show when it is level. Attach heavy drawing paper to the baseboard with Scotch Tape or thumb tacks. Throughout the day, mark the successive positions of the shadow of the nodus (Figure 2). Write the clock time of each shadow next to the position marked. Draw a line from the point directly beneath the plumb bob to each shadow position. Also, draw a smooth curve through the several shadow positions. An example of this record is shown in Figure 3. The geometry of the shadow is diagramed in Figure 4.

Some of the concepts which might be developed, and measurements which might be made through this activity are outlined below.

(1) The *real sun* is that which we see; it emits light and can cast a shadow. The *mean sun* is an imaginary sun which keeps perfect time and by which we regulate our clocks; it does not cast any

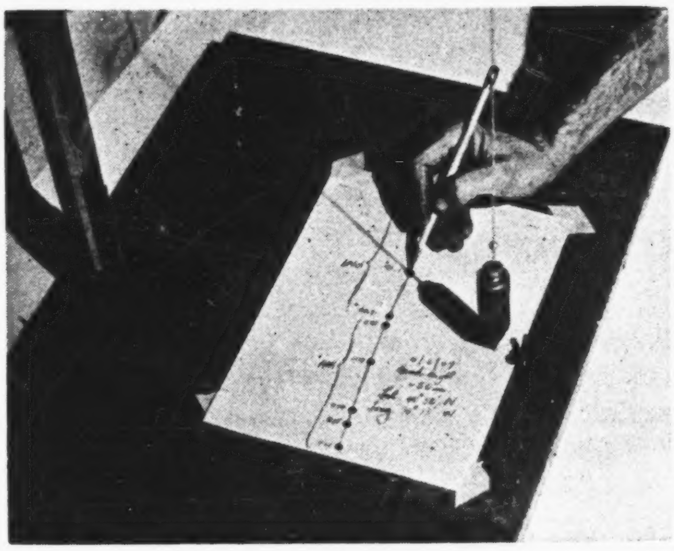
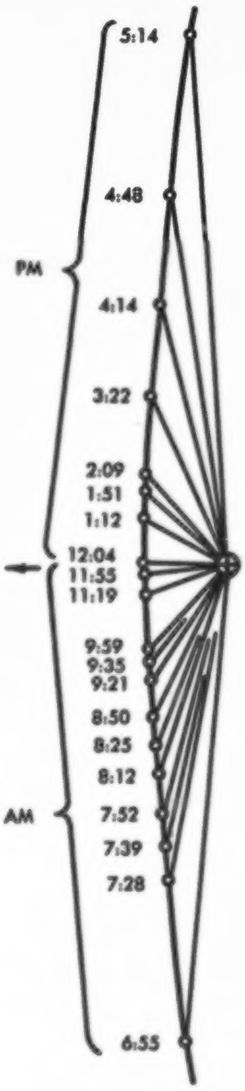


FIGURE 2

The nodus is a bead, or a core from a cork borer. It casts a shadow on the paper which shows where the sun is—how high above the horizon and in what geographic direction. The path of the shadow during a day can be used in answering such questions as what season it is, what instant real solar noon comes, what direction true north is, and where the observer is (latitude and longitude.)



shadow. The difference between real sun time and mean sun time is the *equation of time.* (See Equation (a).)

(2) The *altitude and azimuth of the sun* change throughout the time of daylight. Its altitude is zero at sunrise, increases to a maximum, and then decreases to zero again at sunset. Its azimuth changes as the sun rises roughly in the east, passes to the south, and sets roughly in the west.

(3) *Real solar noon* is defined as the time each day when the real sun is highest in the sky (and shadows are shortest) and when the real sun is on the observer's meridian.

FIGURE 3

Successive positions of the shadow of a nodus which was 2.00 in. vertically above the point marked with a cross in a circle, on 2 April 1949, in Montclair, N. J., at Latitude 40° 50′ N. Longtitude 74° 13′ W. Scale: 1″=4″.

(4) At real solar noon, shadows lie ***true geographic north*** of the objects which cast them. Thus, in Figure 3, true north lies through the shortest shadow; the arrow showing north has been drawn so.

(5) From here on let us consider that Figure 4 is drawn for real solar noon. Then angle CAB is maximum and is the *altitude of the sun when it crosses the observer's meridian;* as measured on the original of Figure 3 this altitude was the angle whose tangent is 2.00 in./1.50 in., the angle whose tangent is 1.33, or 53° 8′. (Tangents of angles can be found in tables of trigonometric functions.)

(6) The *standard time of real solar noon* can be found by reading the shadow record in Figure 3. If no observation was taken at the instant when the shadow was shortest, the time for it can be estimated from the curve and other times recorded.

(7) If the longitude is known, the *equation of time* can be calculated. The following relations hold for any place in west longitude. In Equation (a), each time must be expressed in the same scale. In Equations (b)-(d), longitude is expressed in degrees.

$$\text{(a)}\quad \begin{array}{c}\text{Equation}\\ \text{of time}\end{array} = \begin{array}{c}\text{Time of real}\\ \text{solar noon at}\\ \text{the place}\end{array} - \begin{array}{c}\text{Time of mean}\\ \text{solar noon at}\\ \text{the place}\end{array}$$

$$\text{(b)}\quad \begin{array}{c}\text{Standard}\\ \text{time}\end{array} = \begin{array}{c}\text{Local mean}\\ \text{sun time}\end{array} - \begin{array}{l}\text{4 min.} \times \text{(longitude of}\\ \text{standard time meridian}\\ \text{— longitude of the place)}\end{array}$$

$$\text{(c)}\quad \begin{array}{l}\text{Standard time of}\\ \text{real solar noon}\\ \text{at the place}\end{array} \approx \begin{array}{l}\text{Standard time of}\\ \text{real solar noon}\\ \text{at the standard}\\ \text{time meridian}\end{array} - \begin{array}{l}\text{4 min.} \times \text{(longitude of}\\ \text{standard time meridian}\\ \text{— longitude of the place)}\end{array}$$

$$\text{(d)}\quad \begin{array}{l}\text{Standard time of}\\ \text{real solar noon}\\ \text{at the place}\end{array} \approx \begin{array}{l}\text{Standard time of}\\ \text{mean solar noon}\\ \text{at the standard}\\ \text{time meridian}\end{array} + \begin{array}{l}\text{Equation}\\ \text{of time}\end{array} - \begin{array}{l}\text{4 min.} \times \text{(longitude of}\\ \text{standard time meridian}\\ \text{— longitude of the place)}\end{array}$$

In the example of Figure 3, it was mere coinci-

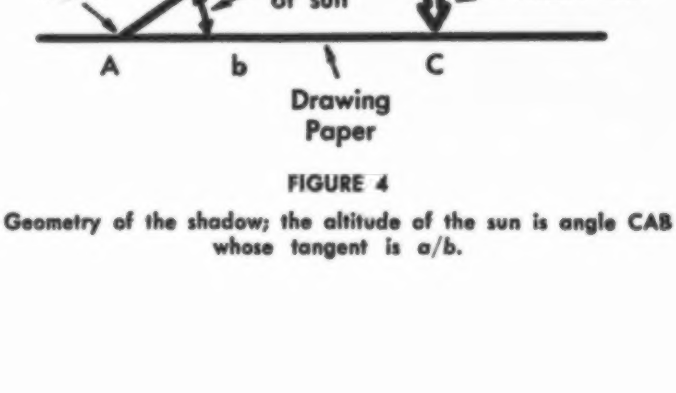


FIGURE 4

Geometry of the shadow; the altitude of the sun is angle CAB whose tangent is a/b.

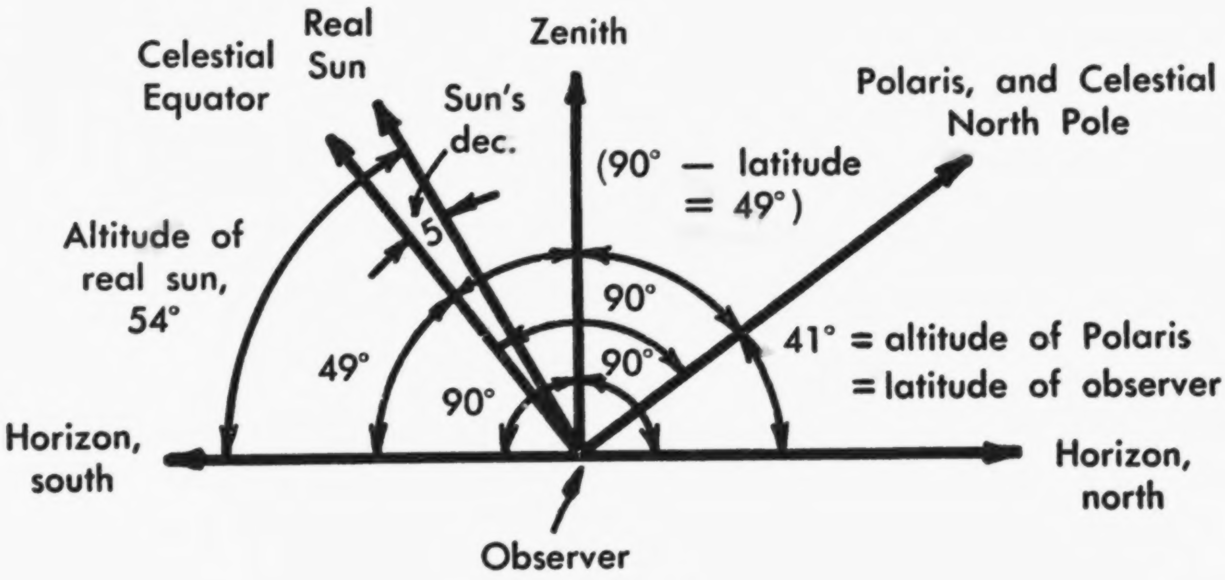


FIGURE 5

Diagram in the plane of the observer's meridian, Montclair, N. J. (Latitude 41° N), at real solar noon, 2 April 1949. The position of the observer has been marked.

dence that *the time when real solar noon was observed* was 12:00 noon EST. Consider the several quantities on the right-hand side of Equation (d). By definition, the standard time of mean solar noon at the 75th meridian is 12:00 noon EST. Assume that we know the equation of time; on this day, 2 April 1949, the real sun was 3^m 37^s behind the mean sun (this is taken from the *Nautical Almanac*)[1]. The map shows my former home in Montclair, N. J., to be 47′ east of the 75th meridian (Longitude 74° 13′ W). When we substitute these values in Equation (d) we get

$$\begin{aligned}\text{Standard time of real solar noon at Montclair, 4/2/49} &\approx 12^h\,0^m + 3^m\,37^s - \left(4 \times \tfrac{47}{60}\right)^m \\ &\approx 12^h\,0^m + 3^m\,37^s - 3^m\,8^s \\ &\approx 12^h\,0^m\,29^s\text{, or } 12^h\,0^m\end{aligned}$$

within the limits of observation.

If we assume the longitude of the observer's place to be known, then the *equation of time* can be found by a rearrangement of Equation (d).

$$\begin{aligned}\text{Equation of time} &\approx 12^h\,0^m - 12^h\,0^m - 3^m\,8^s \\ &\approx 3^m\,8^s\end{aligned}$$

compared with 3^m 37^s taken from the *Nautical Almanac.*

(8) If the sun's declination when it crosses the observer's meridian is known, *the observer's latitude* can be calculated. Figure 5 shows the basis for the following equation:

$$\text{(e)}\quad \text{Latitude of the observer's place} = 90^\circ - \left(\text{Altitude of the sun when it crosses the meridian} - \text{Declination of the sun}\right)$$

From the *Nautical Almanac,* at 12:00 noon EST (17^h 0^m GCT), 2 April 1949, the declination of the sun was 4° 59′. For the situation shown in figures 3 and 4, then, Equation (e) becomes

$$\begin{aligned}\text{Latitude of the observer's place} &= 90^\circ - (53^\circ\,8' - 4^\circ\,59') \\ &= 41^\circ\,51'\end{aligned}$$

compared with 40° 50′ shown on the map.

(9) If the Greenwich Hour Angle (GHA) of the sun when it crosses the observer's meridian is known, *the observer's longitude* can be calculated. The GHA of the sun is the angle measured from the meridian of Greenwich westward to the hour circle of the sun. The longitude of the observer is precisely equal to the GHA of the real sun whenever the observer has real solar noon; that is, whenever the real sun is on the observer's meridian. From the *Nautical Almanac,* at 12:00 noon EST (17^h 0^m GCT), 2 April 1949, the GHA of the sun was 74° 6′. This was also the calculated longitude of the observer, compared with a map value of 74° 13′.

(10) If shadow records like Figure 3 have been made for each of several days throughout the year, the *sun's daily paths in the sky at various seasons* can be compared. In general, a composite of the shadow records will look like Figure 6. The longer

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[1] U. S. Naval Observatory. *American Nautical Almanac for the Year 1949.* Washington, D. C.: United States Government Printing Office, 1948. 318 p. (A similar almanac is issued for each year.)

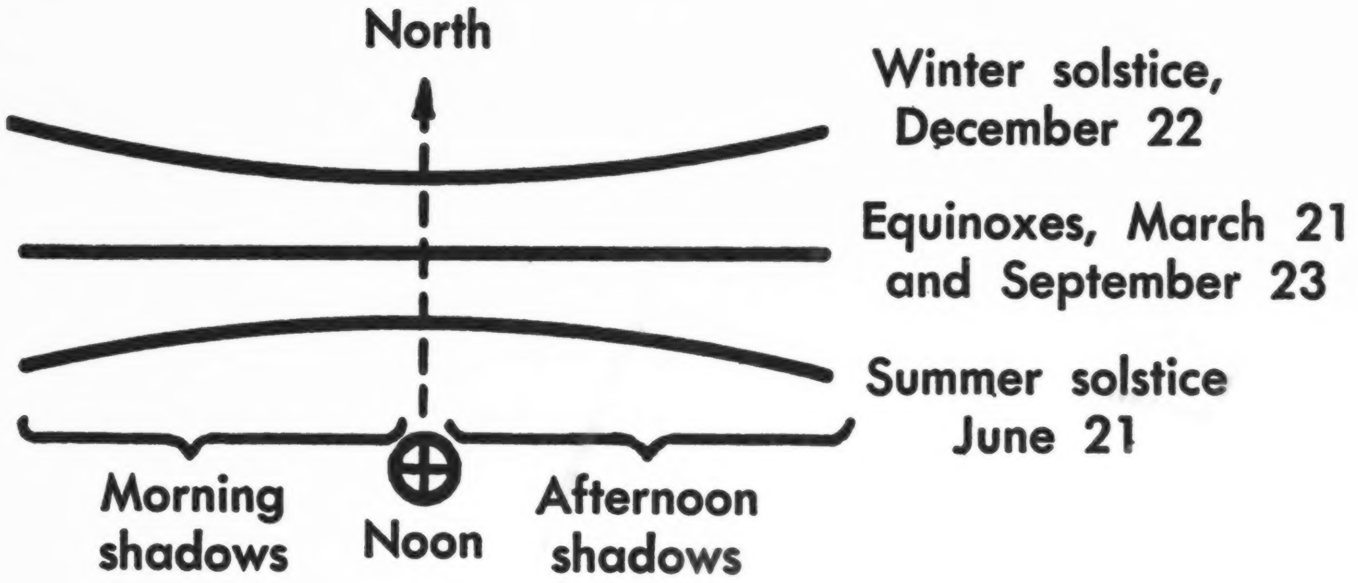
North
Winter solstice, December 22
Equinoxes, March 21 and September 23
Summer solstice June 21
Morning shadows
Noon
Afternoon shadows

FIGURE 6

Range of shadow records (lines drawn through successive shadows of the nodus) throughout the year.

shadows in winter show that the sun is then lower in the sky; the shorter shadows in summer, that the sun is higher. The straight shadow path on March 21 and September 23 shows that the sun rises directly in the east and sets directly in the west on those days. The morning shadow on December 22 lies to the north of west; therefore, the rising sun must be to the south of east. The morning shadow on June 21 lies to the south of west; the rising sun must be to the north of east. Of course, a quick glance at the sun will confirm such shadow observations. But marking the shadow paths is an easy way to make a permanent record of the seasonal variations in the sun's daily path through the sky.

The apparatus in this laboratory activity is simple: essentially it is a plumb line with nodus suspended over horizontal drawing paper. The apparatus has been used in observing the sun through the shadows which it casts. Buffalo weather seems to give more of the shadow than the light, but it would be difficult to find a more pervasive aspect of environment than sunlight and shadows. Concepts such as shadows, sunrise and sunset, forenoon, noon and afternoon, geographic north and south, standard time, latitude and longitude, and seasons have ordinarily been introduced and used long before students reach junior high school. If the development which has been suggested here seems extreme, we may be forced to admit that perhaps we have been using the words without understanding the implications of them with respect to the shadows cast by the sun. The concepts do seem important.

Activities in Astronomy

ARTHUR G. SUHR

Chairman, Science Department, Hamilton High School, Sussex, Wisconsin

(MAY 1961)

THE STUDY OF ASTRONOMY in the average high school is given little emphasis. In this report the author suggests improvement in its presentation by supplementing the material included in the usual high school texts and workbooks with special activities. The demonstrations performed in this astronomy unit can be adapted to meet teaching situations in the general science program and can be used also in other subject areas.

Telescope and Solar Studies

Construction of a telescope was the largest project undertaken. With the assistance of one of the students, construction began of a four-inch reflecting telescope. The component parts were mounted on a board so that the telescope construction and operation could de demonstrated in the classroom and set up for observation as well.[1] The assembly was completed in about six hours during class and in a few evening sessions working together.

Considerable time was spent in discussing the sun. This afforded an opportunity for several worthwhile experiments and demonstrations. For instance, the class may observe the sun for sunspots by projecting its image on a white poster board or screen with a pair of binoculars or a telescope. Many variations of this experiment are possible. The method used in this class was to clamp binoculars on a rod mounted on a standard tripod. The image is best viewed when cast on a shadowed area of the screen. If this project is repeated for several days in succession, the relative positions and size of the spots can be observed each day. Where the spots are large and long-lived, it is possible to show that the sun turns on its axis.

The phenomenon known as the "Northern Lights" or *Aurora Borealis* serves as one example to introduce the study of the sun's radiations. The *Aurora* is formed in part from electrified particles emitted from the sun causing the rarefied atmosphere above the poles to glow. In a class demonstration, this phenomenon may be simulated with a vacuum discharge tube, a piece of apparatus available in many physics laboratories.[2] The influence of the earth's magnetic field on this glow was demonstrated by passing a horseshoe magnet over the vacuum tube and observing the deflection of the purple glow. These demonstrations are described in most physics textbooks.

The ultraviolet portion of the electromagnetic spectrum may be introduced at this time. This was demonstrated with fluorescence by using a General Electric Purple-X bulb as the ultraviolet source.[3] Materials were obtained from advertising firms that use fluorescent inks for printing. The items were mounted on poster board and displayed in class.

Pendulum Project

A unique device for demonstrating the rotation of the earth on its axis is the Foucault pendulum[4] which can be produced from an old shot-put. Suspension of the pendulum, the most important part of its performance, was accomplished by imbedding a hook in the metal shot, attaching it to piano wire, and allowing the assembly to hang from a bracket on the wall. The supporting wire was clamped be-

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[1] Parts for telescopes may be secured from many sources such as the Edmund Scientific Company, Barrington, New Jersey.

[2] C. L. Stong. "The Amateur Scientist." *Scientific American,* 194:132. February 1956; *loc. cit.,* 198:112. February 1958. National Academy of Sciences-National Research Council. *Planet Earth–Classroom Experiments.* Washington, D. C. 1958.

[3] Available from the Welch Scientific Company, 1515 Sedgwick Street, Chicago 10, Illinois.

[4] Richard M. Sutton. "Demonstration Experiments in Physics." McGraw-Hill Book Company, Inc., New York. 1938. p. 90; Thomas E. Thorpe, Jr. "Project Pendulum." *STAR '60 Selected Papers in Science Teaching.* National Science Teachers Association, Washington, D. C. 1960. p. 31; and Stong, *Op. cit.,* 198:115, June 1958.

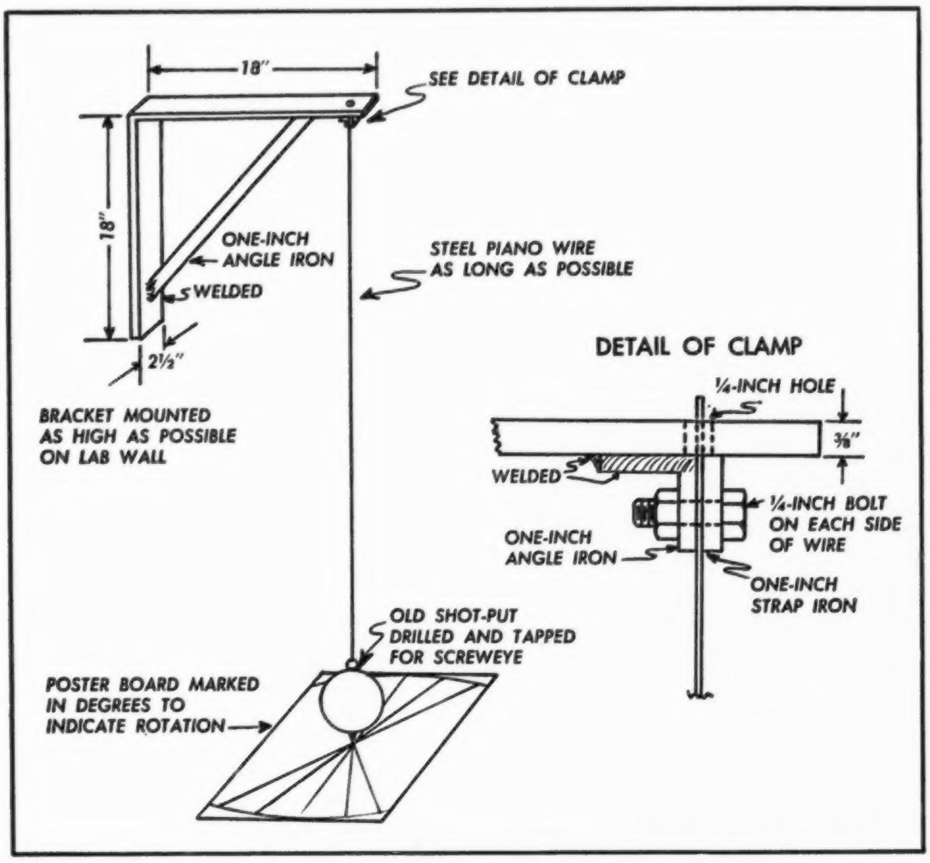
18"
SEE DETAIL OF CLAMP
18"
ONE-INCH
ANGLE IRON
WELDED
STEEL PIANO WIRE
AS LONG AS POSSIBLE
2½"
BRACKET MOUNTED
AS HIGH AS POSSIBLE
ON LAB WALL
DETAIL OF CLAMP
¼-INCH HOLE
⅜"
WELDED
¼-INCH BOLT
ON EACH SIDE
OF WIRE
ONE-INCH
ANGLE IRON
ONE-INCH
STRAP IRON
OLD SHOT-PUT
DRILLED AND TAPPED
FOR SCREWEYE
POSTER BOARD MARKED
IN DEGREES TO
INDICATE ROTATION

FIGURE 1. Detail of Foucault pendulum.

tween two pieces of angle iron welded to the underside of the bracket. (See Figure 1.) To insure accuracy, the pendulum must be completely motionless before the experiment begins. The bob was tied to one side of its natural arc by a string the night before the demonstration. At class time the next day, the pendulum was started in motion by burning the string. As the assembly began to swing, a large piece of poster board is placed under the pendulum. A circle is inscribed on it to mark off in degrees the measurement of rotation in a given period of time. A thorough explanation of the history and outcome of the experiment was necessary for an effective understanding of the demonstration.

Spectroscope Demonstration

The examination of the various spectra with a diffraction grating spectroscope is a student activity which answers the frequent question, "How do astronomers know what stars are made of?" The spectroscope[5] may be constructed by the students themselves with the following materials: a cardboard candy box, two razor blades, a replica diffraction grating, and Scotch tape.[6] A slot about ¼ inch wide and 1 inch long was cut near an edge of the box. Two razor blades were taped over this slot so that their edges formed a narrow slit about ½ to 1 mm wide. An eye hole, ¾ inches in diameter, was cut at the other end of the box, and a piece of the replica grating was taped inside this hole. The grating lines should run in the same direction as the slot. The spectra appear on either side of the slot when viewed through the eye hole. (See Figure 2.)

The spectra sources for this activity were produced from a piece of asbestos paper about 2 inches long by 6 inches wide clamped to a coat hanger wire about 8 inches long. The paper was moistened with water and wrapped around the wire. A mushy solution of each salt used in flame tests—sodium chloride, strontium chloride, etc.—was mixed, smeared over the asbestos paper, and allowed to dry. The specimen was then clamped to a ring stand and heated with a Bunsen burner.

The spectroscope may also be used to examine neon signs or fluorescent lights for a comparison of the spectra produced from these sources.

Time Measurement

Many texts mention the importance of time measurement in astronomy. The author supplemented the information in the textbook by the following method. Since the Bureau of Standards, Station WWV, and the Naval Observatory broadcast a continuous standard-time signal for the United States,

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[5] Fletcher G. Watson. "Shoebox Spectroscope." *Tomorrow's Scientists*, 3:4. January 1959.

[6] Plastic replica grating is available from the Edmund Scientific Company, Barrington, New Jersey.

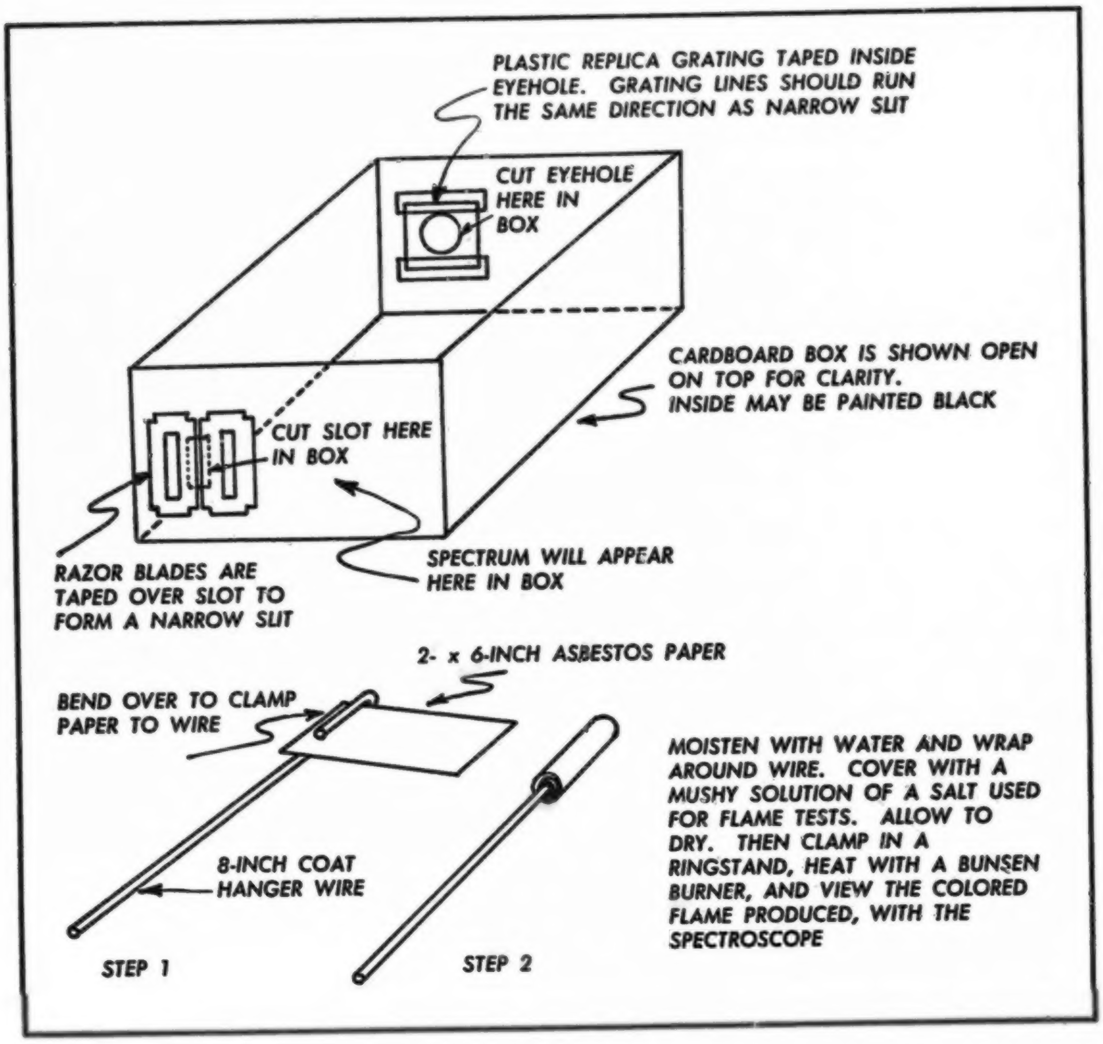
PLASTIC REPLICA GRATING TAPED INSIDE EYEHOLE. GRATING LINES SHOULD RUN THE SAME DIRECTION AS NARROW SLIT
CUT EYEHOLE HERE IN BOX
CARDBOARD BOX IS SHOWN OPEN ON TOP FOR CLARITY. INSIDE MAY BE PAINTED BLACK
CUT SLOT HERE IN BOX
RAZOR BLADES ARE TAPED OVER SLOT TO FORM A NARROW SLIT
SPECTRUM WILL APPEAR HERE IN BOX
2- x 6-INCH ASBESTOS PAPER
BEND OVER TO CLAMP PAPER TO WIRE
8-INCH COAT HANGER WIRE
MOISTEN WITH WATER AND WRAP AROUND WIRE. COVER WITH A MUSHY SOLUTION OF A SALT USED FOR FLAME TESTS. ALLOW TO DRY. THEN CLAMP IN A RINGSTAND, HEAT WITH A BUNSEN BURNER, AND VIEW THE COLORED FLAME PRODUCED, WITH THE SPECTROSCOPE
STEP 1
STEP 2

FIGURE 2. Detail of spectroscope and spectra sources.

the students were assigned to listen to this broadcast and determine its pattern in order to draw some conclusions. For this purpose, a short-wave receiver for signals of three wave lengths (2.5, 5, or 10 mc) was needed. The time broadcasts occurred at five-minute intervals with the first, second, and third minutes carrying a tone signal. Each second was denoted by a beep; the fifty-ninth second was omitted, and the sixtieth was indicated by a double beep. The announcer gave the standard time at the start of a tone signal before the end of five minutes. A new five-minute interval was begun, and the procedure then repeated.

The above experiment may appear over-simplified, but it is useful.

Other Activities

In addition to the experiments and demonstrations described, students in the astronomy unit learned to photograph star trails[7] and experiment with lenses and mirrors to determine how images are formed in a telescope. Through the use of simple thermocouples, an explanation was given as to how star temperatures may be calculated.

The author plans to expand the astronomy unit with some new activities involving "Measurement by Parallax,"[8] "The Law of Equal Areas,"[9] "A Pinhole Coronagraph,"[10] and sunspot photography.[11]

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[7] United Nations Educational, Scientific and Cultural Organization. *UNESCO Source Book for Science Teaching*. New York. 1956. p. 65.

[8] Physical Science Study Committee. *Preliminary Edition of Laboratory Guide No. 2, Part 1*. Educational Services, Inc., Watertown, Massachusetts. August 29, 1958.

[9] Physical Science Study Committee. *Preliminary Edition of Laboratory Guide No. 3, Part 1*. Educational Services, Inc., Watertown, Massachusetts. December 15, 1958.

[10] National Academy of Sciences-National Research Council. *Planet Earth—Classroom Experiments*. Washington, D. C. 1958. p. 4.

[11] Robert W. Ferrell. "Sun Spot Photos." *Mechanix Illustrated*, 55:150. November 1959.

Science Classroom in Orbit

L. JANE STEWART and VICTOR SHOWALTER

Science Teachers, The University School, Center for School Experimentation, The Ohio State University, Columbus, Ohio

(OCTOBER 1962)

THE RELEASE JUST CAME OUT and it read as follows:

EIGHTH GRADERS IN SIMULATED ORBIT

Columbus, Ohio—Four teen-age "astronauts" are in orbit. Their simulated space capsule, U-8, was launched from The University School base at 6:30 p.m. The flight plan calls for sixteen complete trips around the earth in the next 24 hours.

Capsule is loaded with scientific apparatus which will be used in conducting research experiments. A ground crew composed of junior scientists who planned the flight and experiments, is in regular radio communication with the astronauts. First reports indicate . . .

The space capsule and orbit were make-believe. The astronauts, ground crew, apparatus, and research experiments were real. Undoubtedly, also were the science learning opportunities provided by this approach to space-science learning in the junior high school classroom.

The simulated space flight was the climax of ten weeks devoted to Project Phoenix by the eighth graders at The University School of The Ohio State University, Columbus, Ohio. The space capsule was a small eight-by-ten foot windowless room. The astronauts were selected from the eighth grade by the students using techniques borrowed from Project Mercury.

The reason for the "flight" was to obtain data for twenty-two depth studies conceived and planned by individual eighth graders. The only common feature of each experiment was the requirement of 24 hours of hourly data. Problems studied included such subjects as variations in human blood pressure; pulse and respiration rate; sensory fatigue; psychological reactions to food; variations in background radiation and magnetic field; effect of fatigue on mental and dextral ability; and variations in radio reception.

Preplanning Phase

The preplanning phase began with a meeting of staff members from the science department and junior high core discussing ways and means of approaching an eighth-grade unit on space. The unit would last eleven weeks and be staffed by the eighth-grade core teacher and one person from the high school science staff.

The idea of simulating a space capsule in orbit as a focal point for the unit arose from one of the brainstorming sessions. Each student was assigned to carry out an individual depth study and would learn about space from a variety of experiences.

To facilitate the first activity, five weeks of the allotted time would be outlined to develop concepts of space environment and the problems of space flight. It was planned that this time would provide numerous points of departure for individual depth studies.

In providing a variety of learning experiences, many resources were explored. Books were collected including science fiction publications from the school library and placed in the classroom. Pamphlets and films appropriate to the topic were selected and some were requested from reference to a source publication.[1] Since there was no basic text used, the class was urged to buy and read a selected paperback from the Modern Library Series.[2]

Introductory Phase

An introduction to space and space travel was presented to the class by means of lectures, demonstrations, films, and reading. This presentation followed a structured outline:

I. What can we expect to find in space?
    1. The solar system.
    2. Beyond the solar system.
    3. Physical environment of space.
        a. Temperature, radiation, and airlessness.
        b. Gravity and orbits.

II. What are the problems of reaching and existing in space?
    1. The space ship.

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[1] *Pictures, Pamphlets, and Packets.* National Aviation Education Council, 1025 Connecticut Avenue, N. W., Washington, D. C. 1961.

[2] R. W. Buchheim. *Space Handbook.* Random House, Inc., New York. 1959.

Interior of U-8 capsule discloses captain's chair, communications equipment, and materials for several experiments to be conducted while in orbit.

2. The human being.
3. Communication.

Task Forces Established

Many provocative learning situations arose from the problems of planning a "space flight." All problems were delegated to student task forces under the general direction of a space advisory committee.

The task forces were organized for two principal functions: (1) biologistics and (2) research. The biologistic groups provided the requisites of maintaining life in space. Food, water, air, sanitation, clothing, communication, and the capsule itself were included in separate or combined groups. The research task forces directed efforts to crew selection and utilization, orbit plotting, and coordination of individual depth studies.

A small school room, actually an oversized closet, was selected as the capsule simulator. It was equipped with four swivel chairs and several bookcases to contain the experimental equipment. Food and water were packed in polyethylene squeeze bags to permit use in a weightless condition. Sanitary facilities consisted of polyethylene bags ingeniously adapted for use. Air supply was regulated by a system of window fans mounted in the louvered door. Uniforms were white "coveralls" with a distinctive Project Phoenix patch designed in a cooperative art project. A citizens' band radio provided communication.

The selection of a four-man crew was based on a series of physical and psychological tests given to fourteen volunteers. Since each depth study required hourly observations, considerable effort was required to coordinate and schedule each astronaut's time. The schedule of experiments left little free time available to the astronauts.

Research Problems

Each student in the class was required to carry out a depth study. The study was limited only by the necessity that it utilize the unique experimental situation afforded by Project Phoenix; namely, continuous availability of experimental personnel for a 24-hour period of work.

Many problems were proposed. Most fell into one of two categories, physical environment or the psychological-physiological phase. All of the problems required broad reading and generally individuals had to invent experimental procedures and apparatus.

The "Flight"

The astronauts "blasted-off" (with recorded sound effects) after being interviewed by radio and press representatives. Throughout the night and next day, hourly bulletins based on radio communiques were posted by the ground crew. Temperature, humidity, carbon dioxide level, and general crew conditions were reported hourly.

Experiments progressed on schedule inside the U-8 capsule. An unexpected emergency in the form of a ten-minute power failure (the ground crew pulled a main fuse) upset the schedule midway in the flight. The "emergency" was timed to provide data for one of the studies.

Those class members not in the space capsule were organized in two-hour shifts as the ground crew. The ground crew's chief functions were providing moral support for the astronauts via the radio and preparing the hourly bulletins. The regular eighth-grade room became a barracks and most of the ground crew spent 24 hours in school.

After 20 hours in the capsule, one of the crew members became "dizzy and nauseous." He was "jettisoned" through a special escape hatch, planned for just such an emergency, and returned to "earth." The decision leading to his action was made inside the capsule. The three remaining astronauts carried the project to its scheduled completion.

Data Analysis and Reporting

The conclusion of Project Phoenix involved written reports on individual depth studies and summary reports from the task forces. Each individual study was reported orally to the total class and discussed.

In the time allowed for data analysis, the students found that what was expected to be easy became difficult. Hard and fast answers to project problems were not apparent from data. More often, certain answers were "indicated" but not conclusive.

Many of the students attempted correlation of data with that from another study. For example, pulse-rate data were compared to body temperatures and reflex reactions.

Evaluation

What was the point of it all? The newspapers made it sound like fun, but there was more to it than that. At no time did the eighth graders regard the project as a recreational or party activity. From the student's point of view, they were actual scientists investigating real problems in a nearly real situation. From an educator's point of view, Project Phoenix was designed to develop a number of values through the extension or creation of specific attitudes, appreciations, concepts, and skills in learning.

An interest in science, well developed on the part of a number of the boys, had been superficial for the rest, and for most of the girls, was secondary, if existing at all. For those with considerable knowledge, the project extended and deepened interests and revealed new possibilities. For those less interested and less competent, it offered an opportunity to become deeply and personally involved in a science activity that made interest contagious.

For all students, the study offered the opportunity to develop a realistic attitude toward science by removing "space" from the realm of science fiction. It revealed the mass of minute detail which may appear trivial to one without first-hand experience. The necessity for repetition, in defining and testing a problem, the failures which must be viewed as learning situations were experienced by students.

The students learned that space science, being typical of all modern science, cannot be the product of one traditional discipline. To attempt the solution of a problem or find the answer to a question by limiting one's thoughts to physics or chemistry is analagous to running a V-8 engine with one spark plug. Project Phoenix required knowledge of physics relative to the simulated rocket and the planning of an orbit. Required also was knowledge of the environment of space with its attendant problems for sustaining life. Mathematics skills were needed by those plotting the orbit and by everyone in analyzing data. Precise measuring instruments were not always readily available and necessitated the creation of instruments or the adaptation of others. Coordination skills in integrating individual projects were required to insure success.

Throughout the project, both as individuals and as members of task forces, students had to learn to: (1) establish and adapt goals; (2) face failure, and accept it as a learning situation; (3) acknowledge individual differences and plan to accommodate them; (4) make decisions thoughtfully, but rapidly and decisively; (5) adjust to new situations without panic or discouragement; (6) work together by utilizing the supportive roles of the task forces available for consultation and cross fertilization of ideas; and (7) develop awareness of the problems of accurate communication, especially in the area of pub-

Three Project Phoenix astronauts are ready to begin launchingthe twenty-four hour "orbital mission."

lic opinion as represented by the press and by fellow students questioning the group.

Common reading material provided a minimum background experience for all, while individual research reading on general areas of investigation as well as for individual projects honored individual differences and encouraged reading in depth. Recreational reading included familiarity with the best in science fiction.

Writing a scientific paper gave the opportunity to develop research writing techniques: scanning, outlining, developing a bibliography, notetaking, identifying purpose, developing ideas, organizing material, and utilizing transition techniques. Creative writing served an evaluative purpose since standardized tests were not appropriate. Important also were the acquiring of a space vocabulary and the ability to communicate ideas clearly to the press and to the other task forces.

Critical thinking was encouraged on many levels from abstract concepts as free fall and weightlessness to developing international laws regulating space. Seeing new relationships, evaluating steps taken, and projecting plans for the future were values repeated throughout the project.

Representatives of radio and television interview the astronauts after they have "returned to earth."

Astronaut commander checks communication equipment before "blast off."

Conclusion

Were the values hoped for appreciably and demonstrably introduced or extended? Values are difficult to measure. But an examination of the students' scientific papers, experience in evaluating the factual knowledge revealed in project reports and casual conversation, and the demonstrated fact that they used as a final result their skill and knowledge in music to write an original musical drama based on Project Phoenix—these would indicate the answer to be affirmative.

Perhaps even more revealing was the reaction of these students to the Freedom 7 flight under the U. S. program and succeeding flights. Individuals related these experiences to their own experiments on heart beat, psychological reactions, tracking, communications, and gravity. Numerous students immediately reacted to the results reported on re-entry of the U. S. astronaut. More subtle, perhaps, was their identification with not only the astronaut but with the supportive elements in the operation, their understanding of the necessity for checking and rechecking, and their identification with the total experience rather than just one phase of it, as is so often done.

As a learning experience for students and teacher participating in science Project Phoenix—it was A-Okay!

PART B
Biological Sciences

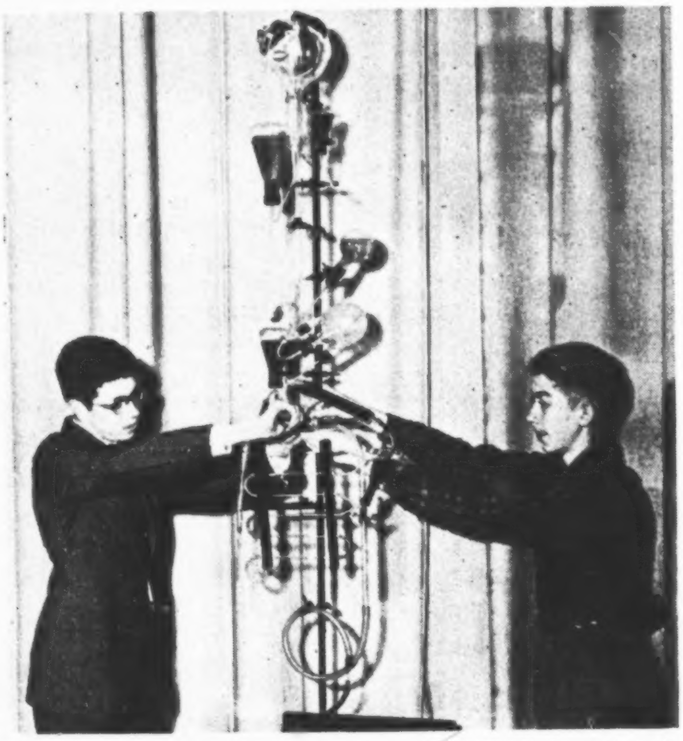
Transparent Model of the Human Digestive System

HOLLIS FRAMPTON and TOM REED

Ninth Grade Students (1952), Wilbur Wright Junior High School, Cleveland, Ohio

(MARCH 1952)

THE AUTHORS spent about 40 dollars and their study periods and many hours after school in building and rebuilding the model shown in the accompanying picture. A complex gas-operation mechanism, designed to operate on compressed air or carbon dioxide was found to be inefficient, fragile, and difficult to operate and was discarded to be replaced by blowing the various solutions into the main fluid column by mouth. With the accompanying picture or the diagram two students could in all probability construct the model in 10 to 15 hours.

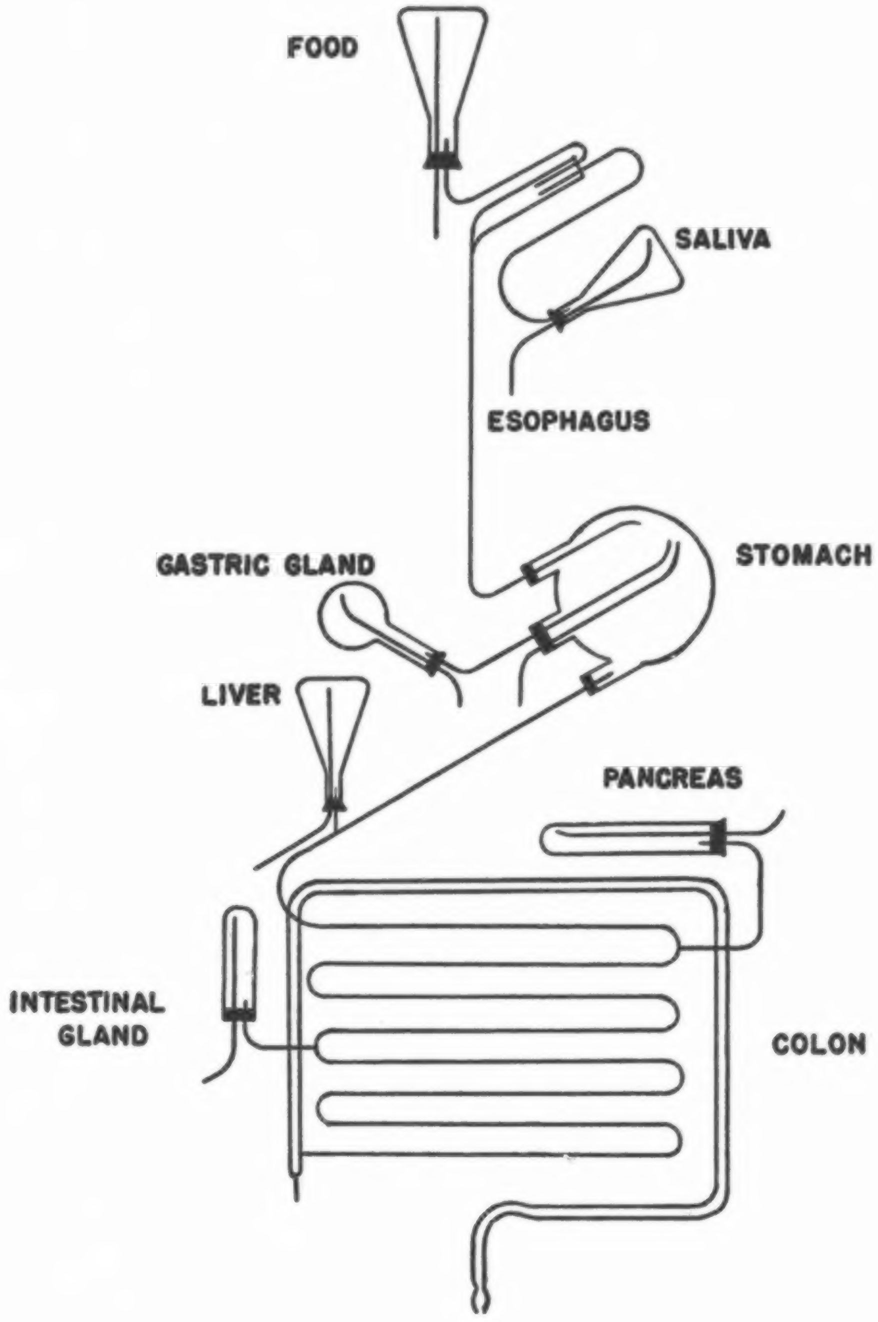


Tom Reed, left, and Hollis Frampton, right, with their model of the human digestive system.

To avoid unnecessary work with glass, Tygon flexible plastic tubing was used. Where tube clamps are used, it is best to use rubber tubing. The entire model was fastened to a six foot, three-eighth-inch steel rod, and the various parts were secured to this support with ordinary burette clamps. A special wooden rack was built for the small intestine. After the final assembly the supporting column, base, and clamps were enameled jet black. Mohr burette clamps were used to clamp the tubing.

It is important to have an air intake for each piece of appartus that represents an organ or gland. All rubber stoppers must have the protective coating removed with carbon tetrachloride, and it is helpful to apply a film of glycerin to glass tubing, especially before insertion into the plastic tubes. It is absolutely imperative that the ends of all glass tubes be firepolished. The ingenious student can probably add numerous small innovations that will improve the operation of the model. The size of the liquid containers depends upon the number of demonstrations desired without refilling.

In the choice of chemical solutions considerable latitude is provided the experimenter. Originally the authors used a rather complex series of chemical changes, but the making of the solutions consumed too much time, and results were not always the best, so the plan was considerably simplified. The present solutions consist primarily of vegetable dyes. This has reduced the cost of operation to less than three cents per demonstration and has decreased the working time of making the solutions. The solutions now used are:



Food Mixture: water—400 ml.
sodium carbonate—5 grams
green vegetable dye—.2 ml.

Saliva: ethyl alcohol—40 ml.
phenolphthalein—1 gram violet dye—.1 CC.

Gastric Juice: water—180 ml.
acetic acid, glacial—20 ml.
yellow dye—2.5 ml.

The final three solutions (bile, pancreatic juice, intestinal juice) are merely solutions of green, blue, and orange dyes in water. The color intensity in all but the "food" and "saliva" solutions should be relatively high. As a test put the solution into a three-sixteenth-inch glass tube; if the color appears bright from a distance of 10 feet, the solution is suitable, if not, add more dye.

Some 30 or 40 demonstrations can be made with the model before it needs to be cleaned. Pouring clear water through it will generally do the job; if not, use a strong solution of sodium carbonate.

A Digestion-Absorption Sequence

MILTON S. LESSER

Chairman, Science Department, Thomas Jefferson High School, Brooklyn, New York

(MARCH 1952)

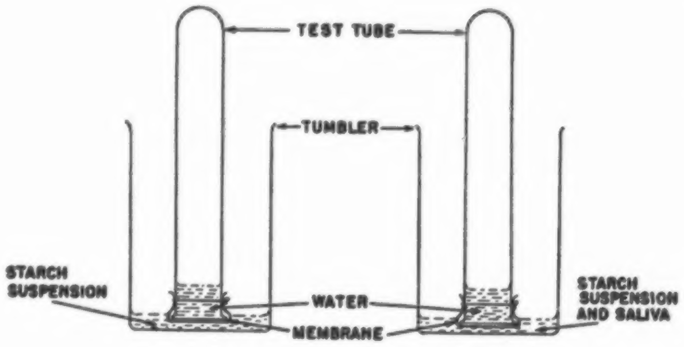
The sequence of activities described below is designed to show salivary digestion and absorption for classes in general science and biology.

Procedure:

1. With iodine solution demonstrate the presence of starch in a boiled starch suspension.

2. With Benedict's solution demonstrate the absence of simple sugars in this starch suspension and in freshly collected saliva.

3. Mix some of the starch suspension with the saliva; keep the mixture warm for five minutes. Before proceeding further, pour some of this mixture into a tumbler to within one-quarter inch of the bottom.



4. Show that simple sugars are present in the original sample of the mixture and in the portion poured into the tumbler.

5. Discussion, recording, etc., should be carried out at this point to elicit the essentials of salivary digestion.

6. A. Pour water into a test tube to within one-half inch of the base. Cover the mouth of the tube with a piece of goldbeater's membrane. Fasten the membrane in place with a rubber band.

B. Invert this tube and set its mouth below the surface of the saliva-starch mixture in the tumbler.

7. Show the absence of simple sugars in another sample of water from the same source as that used in step 6-A.

8. Set up a control with starch suspension alone in another tumbler. Invert another test tube of water in this tumbler as in step 6-B.

9. In about 15 minutes, remove the tubes, rinse them, and remove their membranes and carry out the following:

A. Test the contents of the tube used in step 6 with Benedict's solution. A small percentage of sugar is detectable. (If a longer interval is allowed, or if warm water baths are employed, a more pronounced color change will be evident.)

B. Test the contents of the tube used in step 8 with iodine solution. Starch is not detectable.

C. Carry out any other tests suggested by the pupils.

(Note: An element of realism may be added by substituting a soda cracker for the starch suspension. This may, however, introduce other complicating factors.)

10. Discussion at this point should clarify the principles of the necessity for digestion, as well as the analogy to the absorption by a villus or by a cell.

Values of this method:

1. It permits the drawing of conclusions from observed data.

2. There is provision for thinking with the safeguard of controls.

3. It lends itself to either demonstration or individual laboratory work.

4. The digestive function of saliva is shown.

5. The general concept of absorption is demonstrated.

6. It provides a continuous sequence from the necessity for digestion, to the process of digestion, through the absorption of a nutrient, without the introduction of additional complicating demonstrations.

Action of the Valves of the Heart

DANIEL S. THORPE

Washington High School, Atlanta, Georgia

(NOVEMBER 1952)

The action of the valves of the heart can be vividly demonstrated by the construction and use of a moderately simple apparatus. Plastic tubing is easily handled since it can be sawed, shaved, or glued. A plastic known commercially as "acetate butyrate" is very easily worked, and can be fastened together by the use of ethylene dichloride. This particular plastic can be bent into various shapes by using either hot sand or hot water, or by heating above an open flame.

A plastic tube (2¼ x 3″) closed at one end with a round window (sheet plastic) is placed in the open left auricle, and another tube (1¼ x 3″) in the aorta of a large beef heart. A tube (½ x 21″) attached to a large rubber bulb is inserted in the cavity of the left ventricle through its apex. The other end of the tube carries a small electric lamp, well insulated, to illuminate the interior of the left ventricle. A 7-watt lamp is sufficient to show through the translucent valve leaflets or cusps in both the interior of the auricle and the aorta. Each plastic tube (with window) has a side tube (¼ x 2″) connected by rubber tubing to an aspirator bottle (for pressure) suspended above the heart. The plastic tube (with window) tied into the auricle is connected to a rubber tube at the bottom of the bottle; the plastic tube (with window) tied into the aorta opens at the top of the bottle. A Y-tube is inserted in the rubber tube at the bottom of the bottle. One end of the Y-tube is connected to the side tube projecting from the cylinder (with window) in the auricle. The other end of the Y-tube is connected to a side tube projecting from the plastic tube carrying the rubber bulb. A cylinder enclosing a one-way valve is inserted in the latter tube leading from the Y to just in front of the rubber bulb. Check all connections and make certain the two cylinders with windows are tied securely. The heart is placed in a shallow pan to catch the water in case of leaking.

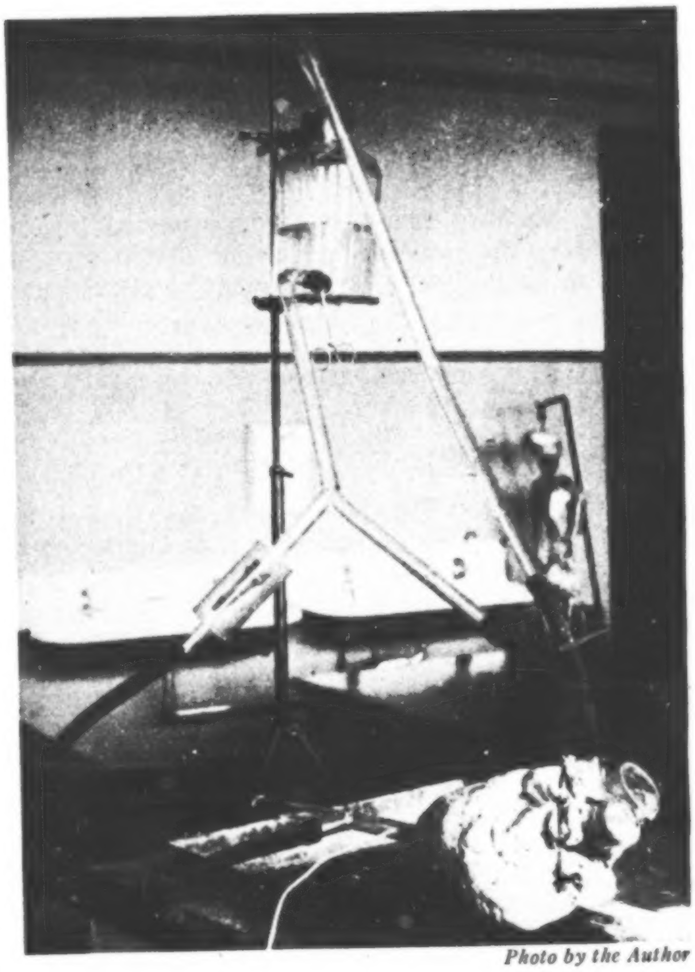


Photo by the Author

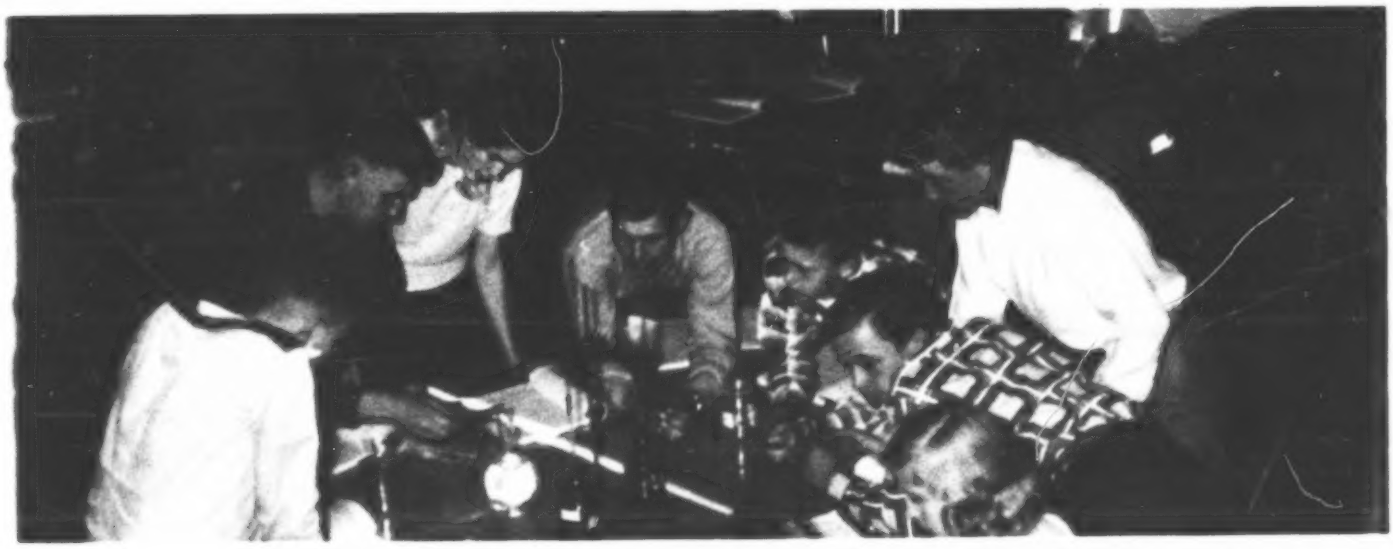
Water is poured into the bottle until the entire system is filled. A moderate supply should be left in the bottle. Alternate compression and release of the rubber bulb will imitate the action of the left ventricle. The action of the valves will be seen through the windows as the pressure of the water rises and falls.

Mendelian Inheritance

C. MICHAEL ADRAGNA

Associate Professor of Science Education, New York University, New York City

(NOVEMBER 1950)



To DEMONSTRATE the Mendelian law in human inheritance in class is often found to be quite difficult. Teachers generally resort to various forms of excellent visual materials for this purpose. However, these teaching aids lack the peculiar conviction associated with witnessing the operation of the law in oneself. In some rare instances where a class member may be used as an example, the teacher is confronted with the delicate considerations of adolescent psychology and hence usually discards the idea. For these reasons it has been found advisable to seek a phenotypic trait that students consider unimportant and that, at the same time, can be easily demonstrated in class. One such trait is found in the physiological sense of taste,

It has been known for some time that persons vary in their ability to detect the bitter taste of a white granular chemical, phenylthio carbamide;[1] some can taste it while others cannot. Furthermore, this difference has been traced to a single pair of genes that follow the Mendelian law of dominance. Accordingly, it has been shown by various investigations that about three-fourths of the American population can taste phenylthio carbamide and one-fourth cannot. Thus, the tasters must be pure homozygous or hybrid heterozygous, while the non-tasters must all be pure recessives.

In class, the procedure has been to dissolve about one gram of phenylthio carbamide in about 20 ml. of water and pass it around with a box of toothpicks. Each student was asked to dip a toothpick into the solution and to taste it.[2] The results have conformed closely with the established ratio.

Additional genetic data on the tasters or non-tasters can be readily obtained by giving each student a sample amount of the solution and requesting him to test the remaining members of his family. Their reports will prove interesting, not only to them, but also to the rest of the class who can attempt to determine the probable genotypic constitutions with regard to the one factor under investigation.

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[1] Scientific supply companies also sell it under the name of thiophenyl carbamide.

[2] Candy was passed around in order that students who experienced a bitterness might neutralize the unpleasant effects.

Soil Preferences of Common Plants

WALTER S. LAPP
Head, Science Department (Retired), Overbrook High School, Philadelphia, Pennsylvania

and **EDGAR T. WHERRY**
Professor of Botany, Emeritus, University of Pennsylvania, Philadelphia

(APRIL 1951)

THE PURPOSE of this article is to call attention to an important factor in plant growth which often is not adequately treated in high school science courses. This factor is the pH of the soil. Many plants and crops will not grow properly unless the pH of the soil is within a certain range. Among the points treated are a discussion of the pH scale, procedures for sampling and testing soils, directions for adjusting the pH value of soils, and a classification of some plants and trees according to pH preference.

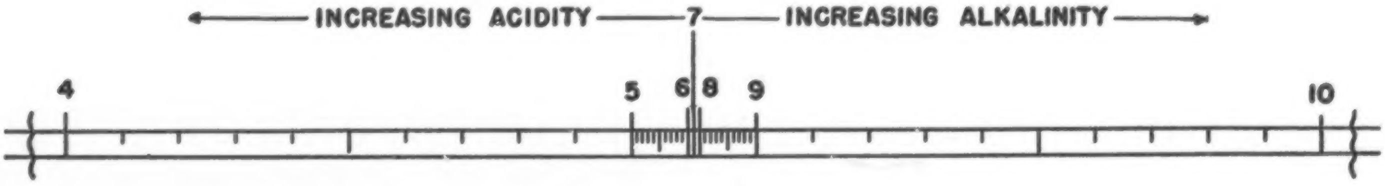
The study of pH-plant-soil relations is a good example of the correlation of chemistry, botany, and agronomy. These relations should constitute a part of the laboratory and field work of science classes. Many students, especially those in rural areas, should find this problem of interest in working out projects for science fairs.

The pH scale is a scheme for measuring the intensity of acids and bases in solution. The scale, which ranges from 0 to 14, is reproduced above. The neutral point is pH 7.0. Any value between 0 and 7 is acidic. Any value between 7 and 14 is alkaline or basic. The relationship between points on the pH scale is logarithmic. Therefore each pH unit is ten times as great in value as the one next approaching 7. For instance:

pH 5 is 10 times as acid as pH 6
pH 4 is 100 times as acid as pH 6
pH 3 is 1000 times as acid as pH 6
pH 9 is 10 times as alkaline as pH 8
pH 10 is 100 times as alkaline as pH 8
pH 11 is 1000 times as alkaline as pH 8

The pH scale is widely used in industry and research as a means of control in all sorts of processes involving acids and bases. LaMotte (9) says:

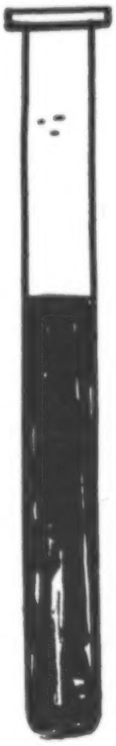
> Today, we find the term "pH" to be a part of the routine vocabulary of practically every technical man, and the usefulness of the subject in general has benefited so many processes that it is now an accepted operating factor.



While the farmer and horticulturist already use some pH control methods, the student and home gardener should also know about it and its significance.

Sampling the Soil. The sample of soil to be tested should truly represent the area from which it is taken. In sampling the soil from a garden or lawn, take five to ten thin slices to a depth of six inches for each 1000 square feet. If the soil is wet, let it dry indoors for a day or two and then make up a composite sample by mixing thoroughly. In testing the pH preference of a wild flower, the sample should be taken from the soil in direct contact with the feeding roots of the plant. In making up a composite sample, do not mix soil from different soil types. Make up a separate composite sample for each type. Do not mix samples that differ in nature such as: sunny and shady areas; wet and dry areas; high and low areas; good and poor crop areas; clay and sandy soil; and dark and light soil.

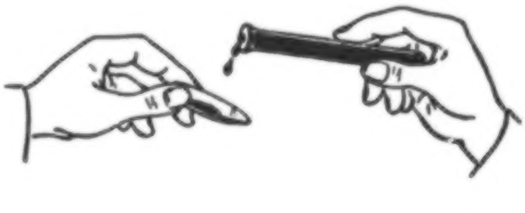
The Indicator. One of the simplest methods of measuring pH values is by means of an indicator or dye, the color of which varies with the degree of acidity or alkalinity—in other words, at different points on the pH scale. The second-named author (**16**) first suggested Brom cresol purple as a suitable indicator for soil tests in 1918 while he was with the United States Department of Agriculture. The advantage of this indicator depends upon the fact that it covers that part of the scale in which most common plants grow. It has sharply contrasting end colors: golden yellow at pH 5.0 or lower, and dark purple at pH 7.5 or higher. It is red-brown at its "midpoint," pH 6.0, which is the lower limit of the large group of circumneutral plants. Harper (**6**) in Oklahoma compared Brom cresol purple with other indicators in testing the pH of over 1000 soils and proposed that it be used in practice.



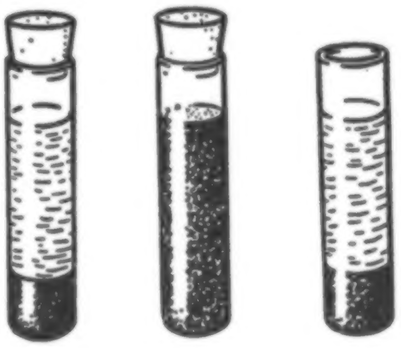
Brom cresol purple indicator solution can be obtained from dealers. If much is needed, it can be prepared by the following procedure. Dissolve one gram of BCP powder in 250 ml. of either methyl or ethyl alcohol. Dilute to a volume of two-and-one-half liters. Add limewater a few drops at a time until the color becomes a distinct red. Preserve in Pyrex containers and add a few crystals of thymol to prevent the growth of organisms.

Testing the pH of Soil

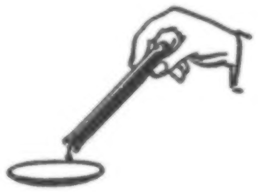
Direct method. By means of a knife blade place a pinch of soil on a small watch glass and cover it with several drops of indicator solution as in the illustration above. Shake or twirl the watchglass gently to mix soil and indicator. After a minute or two the solution will show no further change. Compare with a color chart such as that of Clark (**3**) and interpret accordingly.

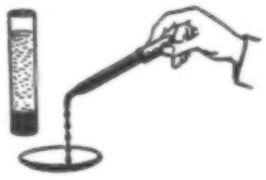


Extraction Method. Mix one volume of soil with four volumes of distilled water (or rain water) as in the tube on the left. Stopper and shake the vial for half a minute. Let the water-soil mixture settle as in the tubes in the center and on the right (not less than five minutes nor more than one day).



Next put one drop of indicator solution on a watchglass as in the top illustration. Then, by means of a medicine dropper, transfer five drops of the clear soil extract to the watchglass as in the lower illustration. Compare with the color chart and interpret accordingly. While the extraction method takes more time, it requires less indicator solution and is somewhat more accurate than the direct method.





The indicator solution may be dispensed from a test tube fitted with a shaker top or from a dropper-stopper bottle. In either case the container should be of Pyrex glass.

Adjustment of Soil pH

The soils of North America vary widely in their natural pH values. The eastern forested soils are strongly acid and are known as "podzols." The black, fertile grassland soils of the central states are near neutral and are called "chernozems." The soils of the desert regions are distinctly alkaline. Among the factors correlated with the natural pH values of soils are total annual precipitation, mean annual temperature, and type of vegetation. In general, soils in humid areas tend to become acid because considerable amounts of the basic elements such as sodium, calcium, and magnesium are dissolved and carried away by percolating rainwater.

Liming Acid Soils. Plants which are decidedly acid in preference require no lime whatever. Those of the slightly acid group may require a small quantity if they are to be grown in exceedingly acid soils. For the circumneutral group the following amounts may be used if the pH is 6.0 or less:

Common Name	Chemical Name	Chemical Formula	Pounds/1000 sq. ft.
Quick lime	Calcium oxide	CaO	40
Hydrated lime	Calcium hydroxide	$Ca(OH)_2$	50
Powdered limestone	Calcium carbonate	$CaCO_3$	80
Powdered dolomitic limestone	Calcium Magnesium carbonate	$CaMg(CO_3)_2$	80

Light soils need less lime than heavy soils (**7**). In adjusting soils of pH 5.0 or less for circumneutral crops, the quantities of limestone to be applied may be of the order of: one to two tons per acre for sandy soils; two to four tons on silt loams; and three to five tons on clay soils high in organic matter (**13**).

Because magnesium is usually available to crops in much smaller quantities than calcium, it is generally a good plan to apply lime in the form of powdered dolomitic limestone. When the magnesium carbonate content is as much as 20 per cent, the limestone is spoken of as "dolomitic" or "high-magnesium" limestone. Pure dolomite contains 45 per cent magnesium carbonate. If too much dolomitic limestone should be applied, no harm will be done because the excess quantity will act like so much sand and will tend to lighten the soil (**2**).

Hydrated lime must be used cautiously because if it comes into contact with a complete fertilizer it will release much of the ammonia from the fertilizer. It is therefore best not to apply hydrated lime and fertilizer at the same time unless each is thoroughly and separately mixed with the soil.

The Functions of Lime. The only practical way to reduce or neutralize soil acidity is to apply some form of lime. Lime performs several distinct functions:

(1) It reduces acidity.

(2) It provides calcium and magnesium, elements which are needed in variable amounts by different plants.

(3) It may make the element phosphorus more soluble and therefore more available to plants.

(4) It reduces the toxicity of excessive quantities of aluminum, iron, and manganese by changing these elements into less soluble compounds.

(5) It makes heavy soils friable and tillable by converting fine clay particles into a crumblike structure. Unlimed soils tend to puddle when wet and on drying become almost as hard as bricks.

(6) It promotes essential biologic processes such as decomposition of organic matter and nitrification.

Acid Soil Beds. Special beds should be constructed whenever decidedly acid plants are to be grown in circumneutral soil areas. Excavate a foot or more of the original soil. Fill in with a mixture of one part acid sand and three parts acid peat, humus, rotten wood, or decomposing oak sawdust. Pine sawdust should not be used because its turpentine content is toxic.

When acid-loving plants are growing poorly on soils which are insufficiently acid, one of the acidifying agents mentioned in the accompanying tabulation should be applied. These materials should be raked into the upper inch of the soil. Many acid soil plants have shallow roots, and great care must be exercised not to disturb them. Furthermore, when the soil has been adjusted to the proper pH, it must never be assumed that it will remain at that value indefinitely. Earthworms are always at work bringing lime up from the subsoil. This tends to neutralize the acidifying agents. Therefore an acidity test should be made at least once a year and the soil pH adjusted accordingly. The following are the chemical acidifying agents generally recommended:

Common Name	Chemical Name	Chemical formula	Pounds/ 1000 sq. ft.
Alum	Aluminum sulfate	$Al_2(SO_4)_3$	25
Flowers of sulfur	Sulfur	S	25
Tannin	Tannic acid	$C_{14}H_{10}O_9$	25

Some Practical Implications

There are many practical implications of pH control of which only a few illustrations can be given. The Romans knew that lime was beneficial to legumes but did not know why. The use of lime in England is an old practice. Scarseth (**11**) in Indiana reported that in controlled field experiments with three- and four-year rotation including legumes $1.00 spent for lime on soils of pH 4.7 returned $12.34; on soils of pH 5.0 the dollar returned $5.70; and on soils of pH 6.0, $3.00.

In Puerto Rico, Gile (**5**) reported 40 years ago that an excess of lime caused chlorosis of pineapples. In other pineapple countries it has been observed that as far back in the fields as the wind can carry the limy dust from gravel roads the plants tend to become yellow and sickly. The excess of lime causes a deficiency of soluble iron and hence the chlorosis (**7**).

Spinach requires a circumneutral soil while potatoes need a moderately acid one in order to keep the scab under control. In lowland Virginia a plan has been worked out by means of which it is possible to grow both crops in the same fields year after year. In the fall when the spinach is planted a light and shallow application of lime is made. The following spring the field is plowed deeply. In this manner the lime is thoroughly mixed to plow depth with the result that natural leaching processes keep the soil acid enough for the potatoes.

In 1937 the first-named author (**10**) noticed from the train that the athletic field of the Reading Company at Tabor in Philadelphia was a patchwork of many kinds of turf. Investigation brought to light the fact that the field was seeded in 1893 and that since then nothing had been applied except lime along the lines marking the areas for such sports as football, soccer, and tennis. On careful examination it was found that along the "lime lines" there was an excellent stand of sturdy turf composed mainly of Kentucky bluegrass and white clover. All other parts of the field consisted of crabgrass, miscellaneous weeds, and a few patches of bent and fescue grasses. Soil tests revealed that the pH along the "lime lines" was about 8.0 and elsewhere about 5.0.

Those responsible for the maintenance of turf on large areas such as athletic fields, parks, cemeteries, estates, and even home lawns can well afford to apply the lesson of Tabor Field. This is not to imply that lime need be applied yearly. In general one application of 80 pounds of dolomitic limestone per 1000 square feet once every five to ten years is sufficient to maintain a satisfactory stand of dense turf providing other factors are favorable.

There have been numerous failures and serious losses in attempting to grow such acid plants as rhododendrons, azaleas, and laurel in soils containing too much lime. Sometimes the lime leaches into the acid bed from nearby walls or driveways. The symptoms are a chlorosis of the leaves. The veins usually remain green longer and are sharply outlined against the blade of the yellowing leaf.

The foregoing examples should suffice to show that pH control is an exceedingly important factor in plant growth. With many crops an abundance of lime is a prime necessity. In other cases it may be a deadly poison. It all boils down to a few facts concerning the availability of certain elements in soil and the individual nature of plants. Intensely acid soils are low in the availability of such important elements as nitrogen, phosphorus, calcium, and magnesium. Yet these same soils are high in the availability of aluminum, iron, and manganese (**12**).

The only safe practice then is to learn the pH preference of the plants one wishes to grow and then apply or withhold lime in accordance with carefully made soil tests.

Classification of Plants According to pH Preferences

The list of pH preferences is not intended to be exhaustive but rather illustrative. Those who wish more information should consult the references at the end of the article. In 1941 Spurway (**14**) published a list of about 1500 pH plant preferences, the most comprehensive list so far published. However, the recently published Eighth Edition of *Gray's Manual of Botany* (**14**) includes over 8000 species, varieties, forms, and named hybrids, found in northeastern North America alone. Gardeners are concerned with thousands of species from other regions too. This indicates how much more research is needed on this subject (**1, 8, 15**). Plants have been classified here as:

Group I CIRCUMNEUTRAL (pH 6.0–8.0)
Group II SOMEWHAT ACID (pH 5.0–7.0)
Group III STRONGLY ACID (pH 4.0–5.0)

This classification is not to be thought of as absolutely rigid. In the main the plants have been observed to thrive best in the ranges where they have been listed. However, some are less particular than others and will grow at values distinctly higher or lower than indicated by their places in the lists.

Group I Circumneutral Plants pH 6.0–8.0

Brownish-red to dark purple with BCP

Native and Ornamental Herbs and Shrubs

- Abelia
- Alyssum
- Barberry
- Bluebells
- Butterflybush
- Campion, Starry
- Canna
- Carnation
- Cockscomb
- Convolvulus
- Cosmos
- Cotoneaster
- Crocus
- Dahlia
- Daisy
- Delphinium
- Deutzia
- Euonymus
- Fleeceflower
- Forsythia
- Four-o-clock
- Gaillardia
- Geranium
- Grape Hyacinth
- Hawthorn
- Hibiscus
- Honeysuckle
- Hydrangea, Pink-flowered
- Ivy
- Jack-in-the-Pulpit
- Lilac
- Marigold
- Mockorange
- Narcissus
- Peony
- Periwinkle
- Petunia
- Poppy
- Primose, Evening
- Pyrethrum
- Sage
- Snapdragon
- Spirea
- Tulip
- Violet
- Wisteria
- Yucca

Crops and Grasses

- Alfalfa
- Barley
- Beets, Sugar
- Cane, Sugar
- Clover
  - Red, Sweet, and White
- Corn, Kafir
- Grass
  - Buffalograss, Canada-blue, Crested Wheat, Grama, Kentucky blue, Merion blue, Ryegrass, Shady blue, St. Augustine, and Timothy
- Sunflower

Food Plants

- Artichoke
- Asparagus
- Banana
- Beans, Most
- Beets, Table
- Brussel Sprouts
- Cabbage
- Cantaloupe
- Celery
- Collards
- Currant
- Grapefruit
- Horseradish
- Kale
- Kohlrabi
- Leek
- Lemon
- Lettuce
- Mint
- Mushrooms
- Okra
- Orange
- Peas, Garden
- Spinach
- Swiss Chard

Trees

- Ailianthus
- Apple, Crab
- Arborvitae
- Ash
- Beech
- Cherry
- Elm
- Locust
- Maple, Sugar
- Mulberry
- Oak, English
- Pear
- Pecan
- Plum

Group II Somewhat Acid Plants pH 5.0–7.0

Light yellow to light purple with BCP

Native and Ornamental Herbs and Shrubs

- Anemone
- Azalea
- Bayberry
- Bearberry
- Beautyberry
- Beebalm
- Bellflower
- Begonia
- Bittersweet
- Blazing Star
- Bleeding Heart, Fringed
- Bluets
- Broom, Scotch
- Calendula
- Candytuft
- Chokeberry
- Chrysanthemum
- Cineraria
- Columbine
- Coleus
- Coreopsis
- Dalibarda
- Eupatorium
- Everlasting, Pearly
- Fern
  - Grapefern, Lady, and Wood
- Fuchia
- Gladiolus
- Goldenrod
- Gourd
- Greenbrier
- Heather
- Hobblebush
- Iris
- Juniper, Creeping
- Laurel, Mountain
- Leucothoe
- Lily
- Lily-of-the-valley
- Nasturtium
- Partridgeberry
- Pear, Prickly
- Phlox
- Pipsissewa
- Privet
- Pussytoes
- Pyrola
- Rose
- Scabiosa
- Selaginella
- Violet, Birdsfoot
- Wintergreen
- Virginia Creeper
- Zinnia

Crops and Grasses

- Buckwheat
- Clover, Alsike
- Cowpeas
- Flax
- Grass
  - Bermuda, Carpet, Centipede, Chewings Fescue, Colonial Bent, Creeping Bent, Creeping Red Fescue, Fine-leaved Fescue, Meadow Fescue, Orchard, Redtop, Sheep Fescue, Tall Fescue, Velvet Bent, and Zoysia
- Hemp
- Lespedeza
- Lupine
- Millet
- Oats
- Rape
- Rye
- Soybeans
- Tobacco
- Trefoil, Birdsfoot
- Wheat

Food Plants

- Beans, Lima
- Broccoli
- Carrots
- Cauliflower
- Chives
- Corn
- Cucumber
- Current, Red
- Eggplant
- Endive
- Garlic
- Gooseberry
- Grape
- Onion
- Mustard
- Parsley

Group II FOOD PLANTS (*continued*)

Parsnip
Peanut
Pepper
Pineapple
Potato
Pumpkin
Raddish
Raspberry
Rhubarb
Shallot
Salsify
Squash
Strawberry
Sweetpotato
Tomato
Turnip
Watermelon

TREES

Apple
Birch
Cedar, Red
Chestnut
Chinquapin
Cypress, Bald
Dogwood, Flowering
Fir, Balsam
Fir, Douglas
Franklinia
Hazelnut
Hemlock
Holly
Juniper
Linden
Maple, Striped
Oak, Most
Pine
Shadbush
Silverbell
Spruce, Colorado
Spruce, Norway
Spruce, Sitka
Spruce, White
Tung-oil

Group III Strongly Acid Plants pH 4.0–5.0

Golden yellow with BCP

NATIVE AND ORNAMENTAL HERBS AND SHRUBS

Alpine-Azalea
Arnica
Blue bead
Bog-Rosemary
Bunchberry
Calla, Wild
Clubmoss
Featherfleece
Fern
  Chainfern and
  Climbing
Galax
Goldthread
Hydrangea, Blue-flowered
Indigo, Yellow False
Iris, Cubeseed
Iris, Vernal
Labrador-Tea
Ladyslipper
Leatherleaf
Laurel, Bog
Laurel, Sheep
Moss, Sphagnum
Orchid, Fringed
Pepperbush, Sweet
Pineweed
Pitcherplant
Pogonia
Rhodora
Sandmyrtle
Solomon's Seal, Dwarf
Stagger Bush
Starflower
Stargrass
Sundew
Swamp Pink
Trailing Arbutus
Trillium, Painted
Turkey Beard
Twinflower
Twisted-stalk
Venus Flytrap
Viburnum, Maple-leaf

FOOD PLANTS

Blueberry, All
Cranberry
Dewberry
Huckleberry, Black
Huckleberry, Box

TREES

Ash, Mountain
Cedar, White
Holly, English
Oak Scrub
Pine
  Jack, Longleaf, Mountain, and Pitch
Spruce
  Black and Red
Sweetbay

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He Reduces to Live

ALBERT L. LONG

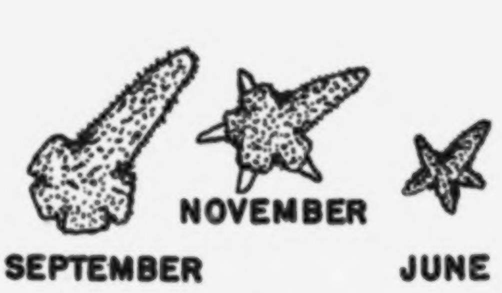
Biology Instructor, Ellenville High School, Ellenville, New York

(APRIL 1951)

Would you like to maintain a living exhibit in the classroom for a school year with no more effort than the addition of distilled water to a large bottle? I had a starfish living in the biology classroom for ten months without food and regenerating four lost arms while doing it.

I found the starfish buried in rockweed at low tide on Hog Island at the Audubon Nature Study Camp of Maine. Four of its arms had been eaten off by some seashore predator. It could just be squeezed into the brown one-gallon bottle which was to be its abode for ten months. The bottle was filled with sea water to a point where the top began to narrow. A mark was placed at the level of the sea water and distilled water was added whenever evaporation was evident. No food was added for fear of contaminating the limited supply of sea water. The bottle was kept in a cool part of the room, but received no artificial aeration. The students and I were fascinated to see the animal steadily reduce in size as the lost arms began to reappear. By June the over-all size was reduced more than a half, the 100 or so tube feet were reduced to gossamer-like threads, but the four lost arms were definitely reformed.

As they peered into the brown bottle, students asked questions regarding regeneration of lost parts, dependency on constant salt-water habitat, contamination of water, and why some animals can live for months without food. This was ample reward for the little time and effort required to keep the show going.



The Big Show

DAVID BENGELSDORF

Science Teacher, Pleasantville Junior High School, Pleasantville, New York

(APRIL 1952)

To every junior high school science room there comes, in the course of the term, a collection of animal life that is indeed fascinating. They are stuffed and alive; both old and young, but a never-ending source of pupil interest. The problem of utilizing these visual representatives of life to the fullest extent is an old one. Too often they remain as decor to enhance the appearance of the room, eventually to gather dust or be sent away. This problem was attacked by the seventh-grade science club of the Bedford Road School in Pleasantville in a somewhat unusual manner which is filled with correlative material.

It was decided by the club that a zoo be formed. There were nine animals in the room at the time: a mallard, squirrel, opossum, and pheasant—all stuffed. Very much alive were the milk snake, "box" turtle, and golden hamster. Each pair of youngsters selected a subject and immediately set out to acquaint himself with that specimen. As the research into the life and habits of the animal progressed several youngsters devised signs to advertise the zoo. The research material was condensed into a talk which was written in their English class, and limited to three minutes as a public speaking project. Two additional minutes were to be allotted to a question period after each presentation. The partners alternated in the presentation and in answering the audience's queries.

Rehearsals were held during the club period, and the zoo was coordinated by an elected "ringmaster." It was presented before the primary grades with the participants frequently switching subjects so that they all became familiar with different forms of animal life.

The enthusiasm for this type of "show" was instantaneous and it was followed by several performances in the upper elementary grades.

This represents one way in which the activities of science clubs can be coordinated with the needs of the school in a manner that is vital and interesting on any grade level.

An Antibiotic Display

HERBERT DRAPKIN

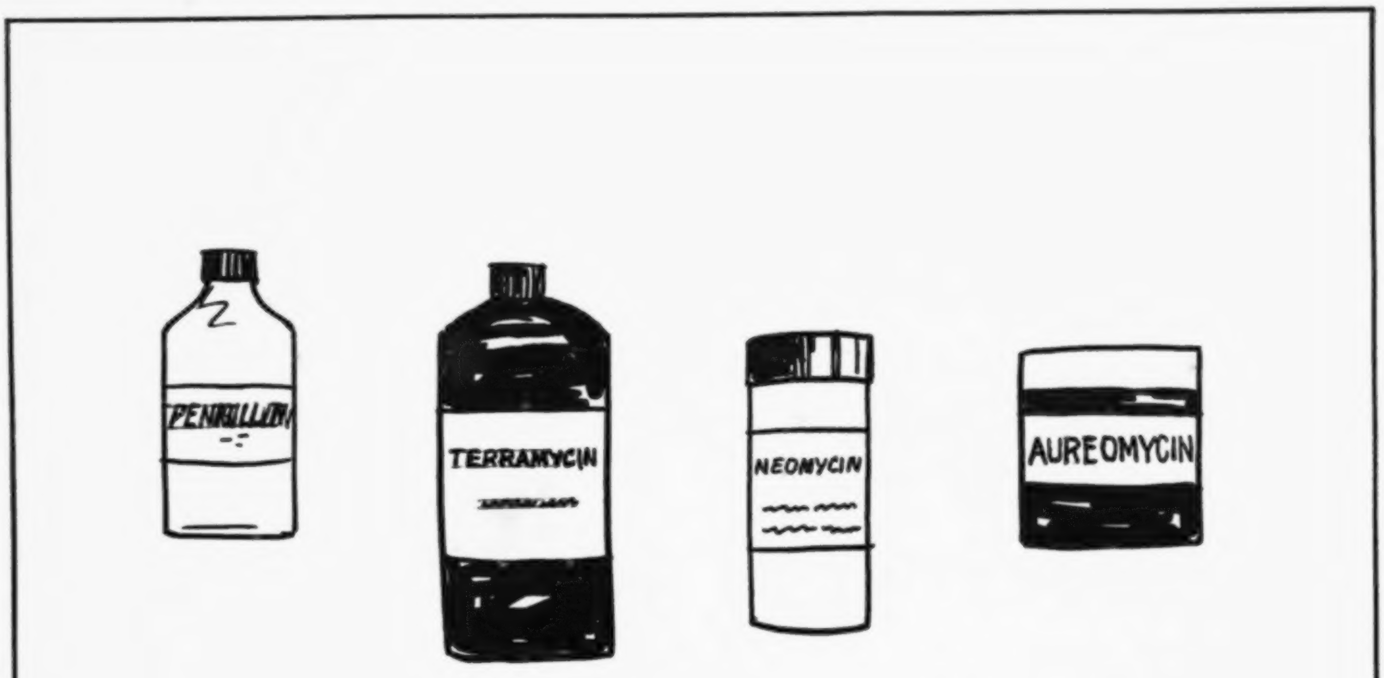
Instructor in Life Science, Fullerton Junior College, Fullerton, California

(SEPTEMBER 1953)

An effective way to introduce the idea of antibiotics in connection with the study of Health and Disease is to have a student-constructed display of empty antibiotic containers. The jars or other receptacles are wired to a sheet of heavy cardboard and sufficient space is provided for large hand-printed names of the antibiotics. Mention of several diseases checked by each antibiotic may also be printed underneath the container.

I have tried this procedure for several years in my classes and the reception by the pupils has been gratifying. There have always been several pupils in each class who knew a pharmacist who could provide them with the necessary containers. Other pupils have been able to contact doctors who have also provided them with illustrated pamphlets as well as the treasured empty container. The pupils interviewed these persons and obtained comments on the uses of antibiotics.

Interesting consequences have resulted from these displays. One enterprising lad obtained first-hand information for his report on the high cost of antibiotics by interviewing an official of a leading pharmaceutical company, as well as his local druggist, his physician, and several scientists in a hospital research laboratory.



Surveying the frozen lake by the plane table method. Measurements were made from the stand to the edge of the shore.

Aquatic Investigation Project

ARCHIE J. NICOLETTE

Chairman, Science-Mathematics Department, Lakeland High School, Minocqua, Wisconsin

(MARCH 1962)

THE IMPETUS to use the fresh water lakes of Northern Wisconsin as a classroom project came as a result of completing a course in aquatic biology at one of the summer science institutes. For a number of years it was my desire to have some of the students actually get to know more about the environment that gives the people in this part of the state its livelihood—the recreation areas. Our lakes are basic to that industry.

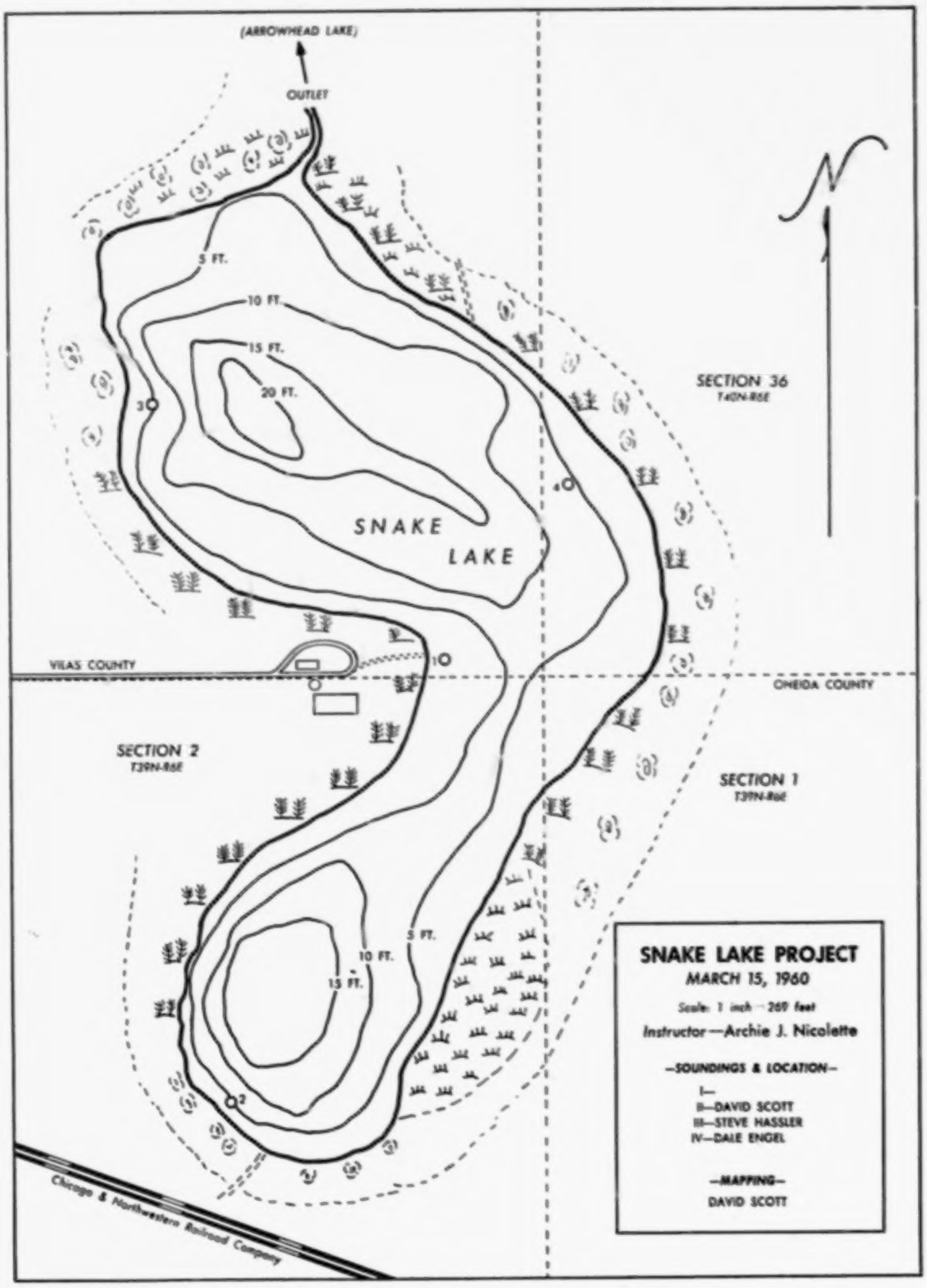
Lakeland Union High School is situated in the "heart of the lakes" region. Within a half mile there are five lakes and just off the campus is a small bog pond. This pond is used by the students to get some practical field work before attempting to do any lake investigations. Within a few miles are located the northeastern headquarters and hatchery of the Wisconsin Conservation Department. Personnel have been available for advice and occasional assistance in our investigations.

It is my belief that some of the better students should realize and actually assist in investigating problems that are confronting our Conservation Department. This activity has a number of objectives:

1. Put the student's classroom education into actual use.
2. Develop scientific thinking, observation, collection, and interpretation of data.
3. Perform actual analysis.
4. Work with biologists in the field.
5. Encourage students to enter the field of scientific research.
6. Enable the students and the teacher to convey their experiences and results to other classes.

Of interest also was to note the avid acceptibility for "out-of-school-time" research projects by students and faculty members. There would be some days when the students did have to be excused from other classes for an afternoon once or twice a month.

It was during a discussion about our project with some Wisconsin Conservation Department officials that they suggested we might attempt to make a survey of Snake Lake, now called Woodlawn Lake. We worked with a biologist assigned to us as a consultant.


(ARROWHEAD LAKE)
OUTLET
N
5 FT.
10 FT.
15 FT.
20 FT.
3
4
1
2
SNAKE LAKE
SECTION 36
T40N-R6E
VILAS COUNTY
ONEIDA COUNTY
SECTION 2
T39N-R6E
SECTION 1
T39N-R6E
5 FT.
10 FT.
15 FT.
Chicago & Northwestern Railroad Company
SNAKE LAKE PROJECT
MARCH 15, 1960
Scale: 1 inch — 269 feet
Instructor—Archie J. Nicolette
—SOUNDINGS & LOCATION—
I—
II—DAVID SCOTT
III—STEVE HASSLER
IV—DALE ENGEL
—MAPPING—
DAVID SCOTT

Above—Map of the project area, which was surveyed by the author's pupils.

Water samples were collected at the surface and one meter below. Students are making use of an alkaline-iodide solution in this experiment.

The Problem and Procedure

Snake Lake is a small lake of fifteen acres in size, and on the east shore is the local sewage disposal plant. Soon after the construction of the plant in 1941-42, the plant's operation was found to be faulty. For a period of years raw effluent was discharged into the lake, so for many years dating back to 1942, Snake Lake has presented a pollution problem. Several surveys have been made in the past to determine the extent of the pollution. As a result of these surveys and complaints by the public, the State Board of Health in December of 1956, ordered all sewage being discharged into the lake to be discontinued. At one time this lake contained a good game fish population. Present information indicates that only forage minnows remain in the lake.

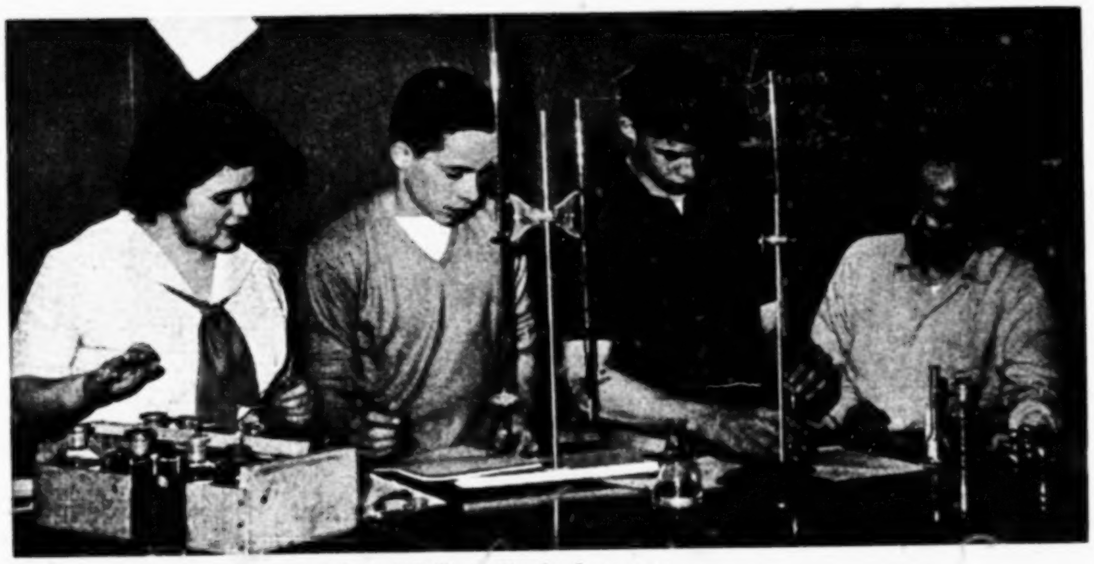
The object of this study was to make a complete lake survey. The data collected could be used by the Wisconsin Conservation Department to determine the best management program for this lake in its present state.

The preliminary work involved mapping the lake, locating vegetation beds, identifying species present, and checking the fish population. This data was used in setting up stations for monthly sampling by the students.

Monthly samples taken included water samples, bottom samples, and plankton samples. At the same time a temperature and dissolved oxygen profile was made. Standard methods were used for water analysis, plankton identification, and bottom fauna analysis. Water analysis involved determination of pH, alkalinity, dissolved oxygen and carbon dioxide, and presence of essential nutrients.

In order to get a true picture of the physical and biological characteristics of this lake, the study period should be from one to two years because of the seasonal change in conditions.

The project was begun with a team of volunteers. Each was selected on the basis of interest, ability and time available. Six students were eventually chosen, three seniors and three sophomores. After the project had been planned, each member was assigned certain duties. The mapping team had to figure out a method to produce a map of the lake with available equipment. They decided on a plane table method with the use of an alidade. Since the lake had become frozen, the survey was easily done, but time-consuming. Sounding was done by chiseling a pattern of holes through the ice. It did not take long for the students to realize that little progress would be made by this method so an ice auger was rented. This method was fast and exciting for the boys. Meanwhile another team was taking water samples.



Students performing the Modified Winkler dissolved oxygen analysis with the author (r.) observing.

Some of the water tests were too difficult for students to perform, so arrangements were made for aid from the Wisconsin State Laboratory of Hygiene. The Committee on Water Pollution was very cooperative in handling some of the tests for us. We sent to the state laboratory a composite sample of 1000 ml obtained at four different locations or stations. The laboratory analysis of the composite sample was for solids, nitrogens, total phosphorus, soluble phosphorus, and pH. The students filled in the field data such as dissolved oxygen content, temperature, and alkalinity at the time the sample was gathered.

The investigation of Snake Lake began in February, 1960 and concluded in June, 1961. The results are being evaluated for a later report.

Thus far a few comments can be made about this scientific undertaking.

Conclusion

Our plans were too ambitious even though the students were capable and available. The instructor was not alloted any time in the school schedule for this type of activity. So, for the project to succeed, work had to be done before school, during noon hours, Saturdays, and whenever time could be sandwiched in. There should be a place in the high school curriculum for activity of this kind.

Teachers and administrators were very cooperative in excusing students from classes. They did insist upon our making arrangements beforehand.

The students also participated with a dedicated enthusiasm which was indicated by the many hours of work outside of school time. Although many extra hours were required by the instructors, every extra hour was challenging, exciting, and rewarding.

A Successful Blood Slide Demonstration

FRANK E. WOLF

Professor of Biology, State Teachers College, Fitchburg, Massachusetts

(FEBRUARY 1955)

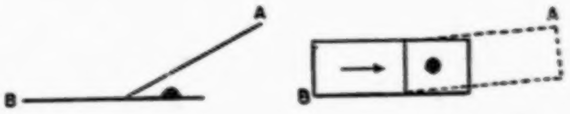
HAVE you ever followed high school laboratory manual directions for making blood slides and been dissatisfied with the results? Upon examining several high school laboratory manuals, it became apparent why teachers in the United States as well as Burma may be unable to identify blood cells on slides made according to some laboratory manual directions. First of all, the usual slide-making technique of putting a drop of water on the slide is absolutely to be avoided in making blood slides because water hemolyzes the red blood cells. Second, the usual method given in these manuals for examining blood is most unsatisfactory; i.e., an unstained slide under high power will reveal very little to the untrained observer. The slide should be stained and if possible examined under the oil immersion 1.8 mm objective. It is true that blood cells may be seen under the high dry objective in an unstained preparation; however, differentiation of cells will not be possible to a satisfying degree to most children and teachers. Third, slides must be scrupulously cleaned and dried, and free from fingerprints.

Following are the procedures for making a good blood smear, staining the smear, identifying the various kinds of blood cells, and counting the cells.

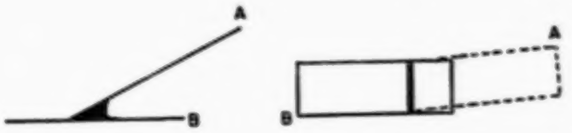
I. Making a blood smear

A. Procedure

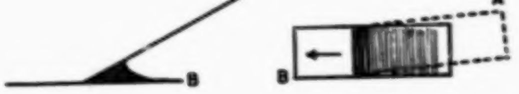
1. Sterilize a needle.
2. Wipe an index finger with an alcohol sponge; dry finger thoroughly.
3. Make a small puncture with the needle.
4. Disregard the first drop of blood and place the second drop near the edge of a clean dry slide (held at the edges to prevent fingerprints).
5. Place the alcohol sponge on the finger wound.
6. Take a new slide ("puller slide") with an intact edge and place at a thirty degree angle on the first slide ("preparation slide").



7. Bring the "puller slide" back to the drop of blood until the blood flows the length of the short edge of the "puller slide" by capillary action.



8. Push the "puller slide" the length of the "preparation slide" maintaining the angle at an even rapid stroke.



9. Allow to air dry and protect from flies.
10. Print identification on the thick end of the slide directly in the blood.

B. Precautions

1. Remove all traces of grease from new slides by cleaning in alcohol or soap and water.
2. Slides must be thoroughly dry.
3. Do not breathe on the slide to hasten the drying of blood as the breath may hemolyze the cells.

II. Staining the smear

A. Procedure

1. The slide is stained with Wright's Stain which may be bought ready for use from most drug houses or drug stores. It may also be made by the class.[1]
   The best procedure is to borrow a small quantity of stain from a hospital or private laboratory.
2. Having obtained a small quantity of Wright's Stain (one-half ounce or so), disregard the standard directions for the use of a prepared buffer solution as this may require a cash outlay and will require practice to determine the optimal staining time. The writer has compared buffers, over a wide range of pH, against neutral distilled water and has found along with co-workers that the neutral distilled water gives satisfactory results.
3. Cover the entire slide with Wright's Stain for the number of minutes recommended by the source of supply.
4. If evaporation takes place, add more stain.
5. After the prescribed number of minutes, slowly add the distilled water while blowing on the slide to mix the stain and distilled water until an equal amount of distilled water has been added to the stain. A greenish metallic coating will be formed on the surface of the stain when the correct proportions have been reached. Add more stain if an excess of water was added.
6. Allow the preparation to stand approximately twice as long as the timing for the stain alone.
7. Flush the slide with water, taking care to float off the greenish coating and using an adequate quantity of water to remove the surplus stain.
8. Dry the bottom surface of the slide with with a paper towel or cloth.
9. Air dry the top of the slide.

B. Precautions

1. The surface of the slide containing the blood must be up to receive the stain.
2. Do not run the stain or distilled water over the edge of the slide prior to flushing.
3. The transferring glassware must be clean and dry.
4. Do not blot slide; you may lose the preparation and/or add lint which will obscure the cells.

III. Identifying the cells[2]

(Use high dry or oil immersion objective.)

All of the following identifying characteristics are for normal cells and a wide variation in these characteristics may be observed.

A. The erythrocytes (red blood cells)

1. Normal red blood cells are non-nucleated, non-granular cells appearing as biconcave discs.
2. The less intensively stained centers give the cells the appearance of doughnuts. These cells are a pinkish red.
3. The cytoplasm is homogeneous.
4. These cells are seven to nine microns in diameter.
5. These will be the most numerous of all the cells on the slide.

B. The leucocytes (white blood cells)

1. Granulocytes
   a. polymorphonuclear neutrophils[3]
      1) irregular nuclei usually with two to five lobes.
      2) nuclei stain deep purplish blue
      3) cytoplasm stains pale pink or violet
      4) ten to fifteen microns in diameter
      5) most numerous of the white blood cells

   b. polymorphonuclear eosinophils
      1) irregular nuclei usually with two to three lobes
      2) nuclei stain pale purplish blue
      3) cytoplasmic granules are large and stained deep red

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[1] Procedures for making Wright's Stain may be found in: Kolmer and Boerner, *Approved Laboratory Techniques*, D. Appleton-Century Company; Todd, James C., and Arthur Sanford, *Clinical Diagnosis by Laboratory Methods*, W. B. Saunders Company.

[2] Details in this section such as size and percents are modified from: *Methods for Laboratory Technicians*, T.M. 8-227, War Department Technical Manual; U. S. Government Printing Office, 1947.

[3] Children often enjoy the full name neutrophilic-polymorphonuclear leucocyte.

4) ten to fifteen microns in diameter
5) one to six percent

c. polymorphonuclear basophils

1) irregular nuclei usually with two to three lobes
2) nuclei stain pale purplish blue
3) cytoplasmic granules are large and stained deep bluish black
4) ten to fifteen microns in diameter
5) least numerous of the white blood cells

2. Agranulocytes

a. lymphocytes

1) nuclei not lobed but may be indented
2) deep purplish blue nucleus nearly fills the cell
3) cytoplasm pale blue to pale pink
4) seven to eighteen microns in diameter
5) approximately half the number of the neutrophils

b. monocytes

1) nucleus round, indented, or horseshoe shaped and turned over on itself
2) nucleus pale bluish violet
3) cytoplasm pale blue or lavender with darker granules
4) twelve to twenty microns in diameter
5) approximately four to eight percent

C. Platelets

1. Platelets are round or oval bluish bodies.
2. Platelets may occur singly or in clumps.
3. It is better to identify clumps as precipitated stain may be mistaken for single platelets.
4. Platelets are one to two microns in diameter.
5. There are approximately one-tenth as many platelets as red blood cells.

IV. Counting the cells

A. Procedure

Count one hundred white blood cells keeping a record of the number of each of the five main kinds of white blood cells, i.e., neutrophils, eosinophils, basophils, monocytes, and lymphocytes. The number of each becomes then a percent of the total number.

B. Precautions

Be sure to cover a wide area of the slide in order to get a representative count. It may be necessary to count two hundred cells before a basophil is seen. Above all do not make any inferences concerning deviations from the normal cell count unless qualified to do so.

Pour Plate Technique

C. LEROY HEINLEIN

Assistant Principal, Gamble Junior High School, Cincinnati, Ohio

and EDWARD E. GELDREICH

Bacteriologist, Water Control Program, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio

(FEBRUARY 1958)

Background

Bacteria are among the smallest and simplest living plants. They are so small that the individual bacterium can only be seen with the aid of a powerful microscope. The largest single bacterium is approximately 1/1000 of an inch long and 1/25,000 of an inch wide. When magnified 1000 times they are often no larger than a pencil point.

Bacteria are divided into three groups: bacillus or rod-shaped, coccus or spherical-shaped, and spirillum or spiral-shaped. They are found in fresh or salt water, in soil, in the air, and in the bodies of other plants and animals. Since they lack chlorophyll with which to help make food, they must obtain their food from external sources just as animals do. Bacteria will grow only in the presence of moisture, food, and other favorable conditions. However, when they have used all of the available food supply, many of them can become inactive and remain in a resting condition for long periods of time. As soon as they again find more food and other favorable conditions, these bacteria immediately start to grow and multiply once again.

When bacteria grow and multiply into many millions of the same kind, this mass of growth becomes visible and is called a colony of bacteria. Many species of bacteria produce a colony with a distinctive shape, texture, and sometimes even a pronounced color. Therefore, some identification

entire bottom. Mix with the 1 ml of raw water by swirling gently. Let the agar-bacteria mixture stand on the lab bench for 5-10 minutes until it hardens. Invert the dish and store it in a dark place to incubate at room temperature for 2 days, or 1 day at body temperature, 98° F.

3. Repeat the above procedure using 1/10 ml as measured using your 1 ml pipette. Repeat using 1/100 ml of polluted water sample. A 1/100 ml amount of sample is obtained by mixing 1 ml of water sample with 9 ml of sterile water previously prepared in a screw-cap test tube or small screw-cap vial or bottle; mark all samples for later identification.
4. Boil the polluted water sample for 5 minutes. Cool to room temperature and make pour plates as in 2 above. Use only 1 ml for this part of the experiment.
5. After incubation, the 1, 1/10, and 1/100 ml pour plates of the original polluted water, and the one plate of boiled water should be observed for bacterial colony growth. It is not possible to identify coliform bacteria on these plates because the medium used does not produce the distinctive sheen needed for identification. Observation and colony counts can be made, however, using a bacterial colony counter. Note the differences in counts between the polluted sample and the boiled water. Point out the advantages of boiling any unknown water before using it for drinking water. Make graphs or charts of the quantities and types of colonies found in different water sources. Check the effect of disinfectants and antiseptics on bacterial cultures. What bacterial cultures can be obtained using the same procedure with milk samples?

Notes on construction of bacterial colony counter

Build a wooden light-box to contain a 25-watt electric bulb. Make a hole the size of a petri dish in the slant side of the box. Place a glass plate over this opening and rule vertical and horizontal lines on this plate about one-half of an inch apart with India ink. These lines become guide lines for counting all the colonies in the petri dish in a

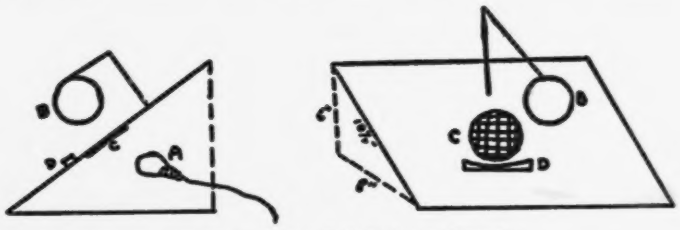

Figure 1. Bacterial Colony Counter

A. Light source—25-watt bulb
B. Lens—4½"
C. Opening covered by lined glass—size of petri dish
D. Wooden block—rest to hold petri dish

systematic way. This avoids counting the same colony twice while scanning the plate from left to right and from top to bottom. A support of wood must be placed on one end of the box to hold a large hand lens or reading glass (about 4X power). This makes it easier to see the small-sized colonies. (See Figure 1.)

Application of the pour plate technique

This is a basic bacteriological method used daily in many different problems in microbiological laboratories in industry, hospitals, and public health. Examples where this method might be used are:

1. to study the effectiveness of new bacteria killing agents—antiseptics, cough drops, antibiotics;
2. to check on food utensils in public eating places;
3. to check for bacterial blood infections;
4. in the control of food spoilage;
5. in the determination of bacterial content of milk.

Streak plate technique

This bacteriological procedure is another of the methods most often used to separate different kinds of bacteria from a mixture. This technique does not provide the bacteriologist with a count of the bacteria present in the sample; it is only used to isolate and differentiate between colonies. The bacterial count can be made later using the pour plate method. This is an adaptation of a method initiated by Robert Koch in the 19th century. Streak plates are made by first pouring the sterilized is possible without the aid of a microscope. The bacteriologist usually studies the reactions of single species or kinds of bacteria. He tries to find what nutrients or food materials a particular kind of bacterium likes best; what types of sugars it will ferment, the way it is stained by various biological dyes, and many other procedures which might help identify that particular organism.

The student should read some references on bacteriology (the study of bacteria) and discuss the experiments with the biology or science teacher before doing any of the laboratory work. Even though the bacteria encountered in these experiments are probably harmless, the student should wash his hands in soap and water after completing the experiments and never put any of this material to the mouth. No food should be eaten in the laboratory. The culturing of bacteria requires adequate preparation of sterile nutrients and materials which should be done by the teacher.

Water is examined daily in many public health laboratories throughout the world to be certain it is safe to drink. The bacteriologist does not look for disease-producing bacteria directly because their discovery requires special techniques and skills. To look for the disease-producing bacteria might be compared to looking for a needle in a haystack. Instead, the bacteriologist looks for the kinds of bacteria which are always present in human waste or feces. Such a group of bacteria are called the coliform bacteria. Whenever these rod-shaped coliform bacteria are found in a water sample, it indicates that this water has been polluted with human feces.

As has already been mentioned, the study of bacteria requires the use of many different kinds of tests. One test method used to see and count living bacteria in some of the bacteriological research problems at the Taft Sanitary Engineering Center is called the pour plate technique. In this method, the bacteria are carefully mixed with a bacterial food material such as nutrient agar in a special culture or petri dish. The petri dish with the mixture of bacteria and nutrient agar is then stored for one or two days at body temperature 98° F or room temperature. During this time, each bacterium grows and multiplies into many millions of the same kind. This results in a cluster of bacteria or colony big enough to see without a microscope. A colony is generally white in appearance and about the size and shape of a pinhead when seen in the nutrient agar. All colonies are counted and the number of colonies represents the original number of individual bacteria present in the sample.

Statement of problem

The purpose of this experiment is to show the student how the bacteriologist can observe the density of bacteria in a sample. Water is suggested in this experiment because it is relatively easy to demonstrate the high numbers of bacteria present in river, lake, well, or spring water as contrasted to few or no bacteria that might be seen in boiling the same polluted water and then making pour plates.

Materials

A. Water sample—river, lake, well, or spring
B. Sterile supplies—a large pressure cooker—sterilize 15 minutes at 15 pounds
    Several bottles of nutrient agar
    Pipettes, 1 ml, graduated in 1/10 ml
    Sample bottles, wide mouth, for water samples
    Petri dishes
C. Bacterial colony counter—could be made as a science project (see directions)

Procedure

1. Melt a bottle of sterile nutrient agar by heating it in a pan of water. After the agar is completely melted (no visible lumps of solid agar), cool to

42-45° C, the pouring temperature. Agar hardens at about 40-42° C.

2. Place 1 ml of polluted water sample in a sterile petri dish using a sterile 1 ml pipette. Pour enough melted agar in the same petri dish to cover the

agar into a petri dish and allowing it to harden. In this experiment the streaking plates are made using EMB agar (eosin methylene blue agar).

Procedure

a. Bacterial suspension. Prepare by mixing several surface colonies from the pour plates used in the preceding experiment in 9 ml of sterile distilled water contained in a screw-cap tube. Use a nichrome wire needle or loop to put the bacterial colony in the water.

b. Cap the tube and shake to get a uniform mixture of the bacteria.

c. Use a nichrome wire needle, sterilized by heating in a flame until it is "red hot." Then it is cooled a moment, dipped about 1 mm deep into the bacterial sample and spread lightly across a prepared streak plate of EMB agar as shown in Figure 2, proceeding from A to D.

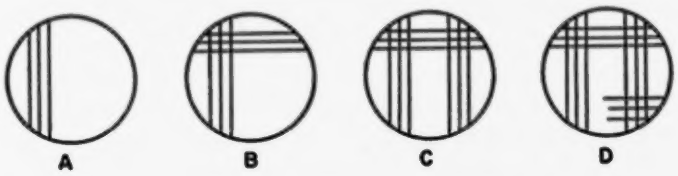

Figure 2. Streaking Sequence

d. Bring the needle in contact with the agar surface in a manner that will avoid scratching or tearing the agar. As the needle is streaked across the plate, the bacteria are separated and spread out with each streak. Fewer colonies of bacteria appear on the last streaks made than appear on the first streaks. (See Figure 3.) This enables the bacteriologist to obtain isolated colonies for study.

e. Invert the plate and incubate at 35° C for about 24 hours (use incubator).

f. Observation of the plate: examine the colonies on the plate (a magnifying lens is not necessary) noting those that have a greenish metallic sheen or lustre (E. coli) and those that are fish-eyed—gelatinous (A. aerogenes); E. coli and A. aerogenes represent two of the more common members of the coliform bacteria. These colonies indicate pollution of the water sample. All other types of colonies present on the plate are not important in this test for pollution, but they represent the bacteria normally living in water.

g. Follow up the experiment by:
   1. sketching or drawing the E. coli or A. aerogenes colonies that develop on the plates;
   2. recording the numbers and descriptions of colonies that appear on the plates but are not necessary for testing pollution;
   3. testing other samples of water or other liquids using the streak technique;
   4. examining specimens of the colonies with the lens of the colony counter.

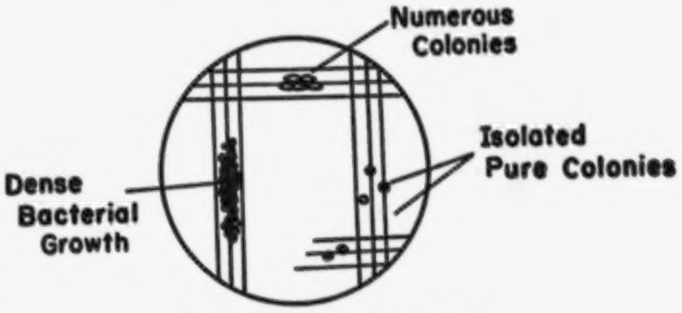

Figure 3. Streak Plate Isolation

Application of streak plate technique

This method can be used to:

a. Isolate bacteria

b. Maintain a pure culture.

c. Identify partially, or tentatively, a species by colony characteristics.

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Teacher

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Culturing Bacteria on Membrane Filters

C. LEROY HEINLEIN

Assistant Principal, Gamble Junior High School, Cincinnati, Ohio

and EDWIN E. GELDREICH

Bacteriologist, Water Control Program, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio

(OCTOBER 1958)

Background

Bacteria are most often found in nature as mixtures of organisms of different kinds. Little information can be obtained with any certainty about the types of bacteria and their activities until they have been separated from the mixture and grown in the presence of bacterial foods or media.

One of the most recent methods used to separate (isolate) and grow (cultivate) bacteria makes use of the membrane filter. This technique applied to the bacteriological analysis of water samples was developed at the Robert A. Taft Sanitary Engineering Center. This method makes it possible to complete a test on water samples in 20 hours as compared to from 48 to 96 hours by the conventional procedure. In this technique, a filter is used to separate or "screen out" bacteria from a fluid such as water.

The membrane filter is made from a thin sheet of cellulose plastic. The filter, about the size of a half dollar, contains over 480 million tiny pores. Each pore is only 0.45 microns in diameter. One micron equals 1/25,000 inch. Since bacteria are one micron or larger in size it is impossible for them to get through the small pores of the filter. Thus the bacteriologist has a rapid method of separating the bacteria from a fluid.

By placing this filter, with the bacteria trapped on its surface, in contact with a suitable food source, each living bacterium is able to grow and multiply into a visible mass called a colony of bacteria. Therefore each colony is the result of growth from a single living organism which was trapped on the membrane filter during filtration.

The identification of the thousands of different kinds of bacteria is a very difficult problem. Bacteria have very few physical differences which can help us tell one from another. These organisms can be divided into only three groups: bacillus, coccus, and spirillum. There are hundreds of kinds in each of these three groups so other means must be used to further separate the different bacteria. Many of these bacteria may be identified by their reactions in special media which contain various organic chemical substances such as carbohydrates, proteins, and alcohols. These tests can only be done with pure cultures of the unknown organism. A pure culture is one that must be free of any other kinds of bacteria which might interefere with its growth reactions in various media. Organisms must be isolated so that when a reaction occurs it is possible to identify the organism producing it.

As an example of the problem of identification of bacteria, the typhoid bacterium (*Salmonella typhosa*) and a common bacterium *Escherichia coli* which is found in soil, water and human feces are both rod-shaped organisms. They look very much alike under the microscope. However if a pure culture of *E. coli* is grown in a lactose sugar medium at body temperature, it will produce visible gas bubbles in 24-48 hours. If a pure culture of the typhoid organism is grown at body temperature in another tube of lactose sugar medium, it will not produce any visible gas bubbles in periods as long as 30 days. Obviously these two kinds of bacteria are different. In the following laboratory exercises, identification of bacteria will be made using both chemical reactions and physical appearance.

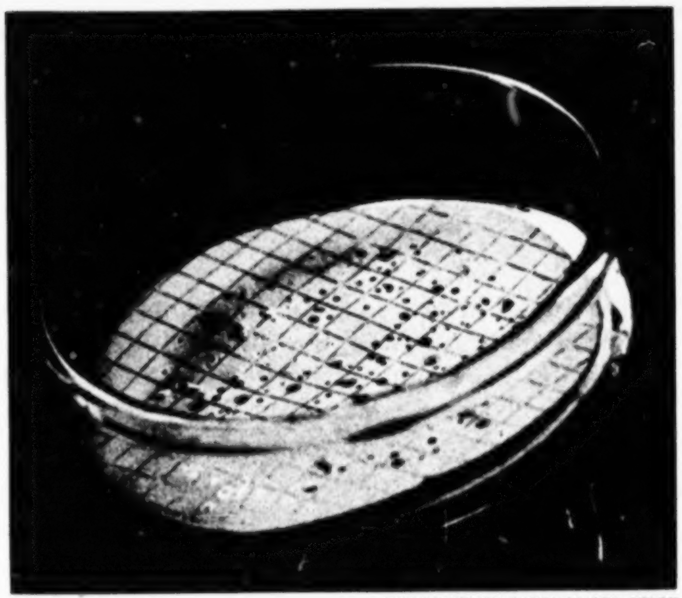
One word of caution, even though bacteria encountered in these experiments are probably harmless, the student should always use the same care in working with these bacteria as he would if they were disease-causing organisms. Wash hands in soap and water after completing the experiments and never put any of this material to the mouth. No food should be eaten in the laboratory. The culturing of bacteria requires careful preparation of sterile nutrients and materials *which should be done by the teacher.* For reliable results, it is recommended that the teacher set up and perform the experiment beforehand to be sure of the sterility of the materials, that the necessary supplies are available and to secure the proper density of the bacterial sample being used.

Statement of problem: The purpose of this experiment is twofold: to familiarize the student with a new basic tool used in microbiology, and to provide the student with an opportunity to use the tool in securing a more rapid, accurate, and less expensive determination of bacterial pollution in water. Formerly 48-96 hours were required to detect bacterial pollution in water; the membrane filter technique reduces this time to 18-20 hours. Water is suggested in this experiment because clean or polluted samples are readily available, it is easy to use, and pioneering applications of the membrane filter were based on the use of water.

Materials

1. *Bacterial sample*

A water sample obtained from a river, lake, polluted well or spring can be used. Choose a quantity of polluted water which gives, after filtration, from 20-60 coliform bacteria on the membrane filter. Thus the colonies will not be too crowded for counting and identification. If raw surface water is used an idea of density can be obtained by using the membrane to filter several samples (3) of 0.01, 1, and 10 ml of polluted water. To obtain a 0.01 dilution take 1 ml of the polluted water and dilute with 99 ml of sterile distilled water. Label this bottle "A." One ml of this mixture is equivalent to 0.01 ml of the sample. One and 10 ml samples of polluted water can be used without the dilution procedure. If sewage is used, filter dilutions of 0.00001, 0.0001, and 0.001 ml. To obtain a dilution of 0.001 of sewage, repeat the dilution procedure outlined for bottle "A" using sewage in place of raw surface water; 0.1 ml of this mixture is equivalent to 0.001 ml of the sewage sample. Take 1 ml of sewage and water mixture just prepared, add 99 ml of sterile distilled water. Label bottle "B." One ml of mixture in bottle "B" is equivalent to 0.0001 ml of the original sewage sample; one-tenth of a millileter of the 0.0001 sample is equivalent to 0.00001. Some idea of the density of coliform bacteria in drinking water from wells, cisterns, springs, or hydrants can be obtained by filtering 10 ml, 50 ml and 100-200 ml of water. Drinking water standards allow only an occasional coliform organism per 100 ml, therefore drinking water can be used as a control in the comparison of organisms in polluted water.



PUBLIC HEALTH PHOTO BY DON MORAN

Membrane ready for counting colonies

2. *Special supplies and equipment* [1]

- a. Filtration equipment
  - (1) Field Monitoring Kit
  - (2) Sanitarians Kit
- b. Membrane filter media
  - (3) Phenol Red Lactose Broth
- c. Colony counting light

3. *Other laboratory materials:*

Pipettes, 1 ml and 10 ml
Graduate, 100 ml
water sample bottles, wide mouth
Dilution bottles, graduated at 99 ml
Incubator—35°C
Hand magnifier, 4X
Gram stain materials:
- a. Gentian Violet Solution
- b. Gram's Iodine Solution
- c. Alcohol 95%
- d. Safranin 1% solution

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[1] For sources from which to obtain supplies and equipment, write to Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio, attention of authors, or consult references listed.

Nichrome wire needle or loop
Test tubes (several sizes)
Microscopic glass slides
Microscope with oil immersion objective

Procedure

Choice of Membrane Filter Procedures

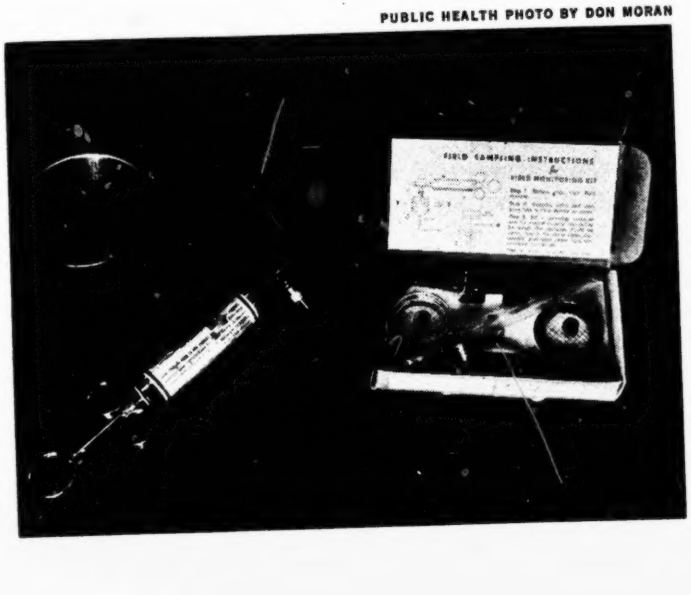
Two procedures for filtering water samples by the membrane filter are possible—the Field Monitoring Kit and the membrane filter laboratory procedures. Both methods use the membrane filter. The directions for using the Field Monitoring Kit are presented in this experiment because it is a technique involving prepared materials which have been sterilized and made ready for immediate use. The membrane filter laboratory procedure requires more preparation of materials and sterilization of equipment but is more economical in cost when many samples are to be examined each day. Consult the references for the complete procedure.

Sterilization of Materials and Equipment

It is suggested that this should be done by the teacher. A large pressure cooker can be used to sterilize all the necessary glassware, pipettes, sample bottles, and tubes of phenol red lactose broth medium (directions for preparation on the container). The sterilization for all glassware and distilled water should be at 15 pounds pressure for 15 minutes. The tubes of phenol red lactose, used in part "A" of the Follow Up, are to be sterilized for 10 minutes at 10 pounds pressure. Do not exhaust the vacuum after sterilizing the lactose, but let the pressure return to zero by gradual cooling.

Field Monitoring Kit

PUBLIC HEALTH PHOTO BY DON MORAN



Field Monitoring Kit

The Field Monitoring Kit (see photo) used in the experiment consists of a membrane filter in a disposable plastic container that serves both as a filter and incubation unit, a plastic sampling tube, medium ampule and instruction sheet. All materials are sterile and ready for use. A Sanitarians Kit consisting of a syringe, valve and a stainless steel sampling cup will be necessary for a vacuum source. Both single and double kits are available. The Sanitarians Kit can be used repeatedly. This procedure should be demonstrated by the teacher before students attempt to use it.

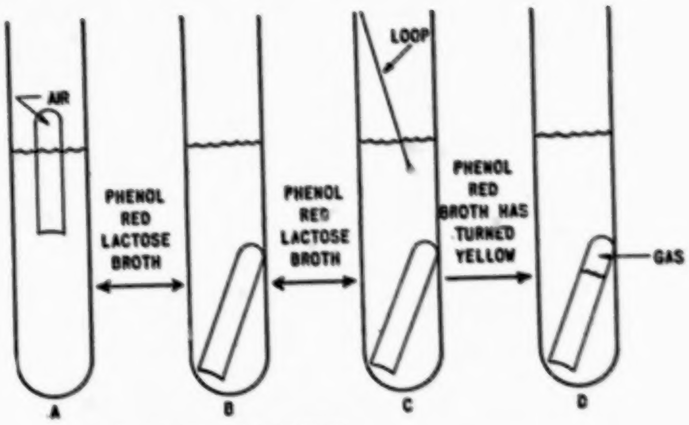
Filtration Procedure:

1. A measured volume of the water sample is placed in the stainless steel sample cup. Proper amount of sample to use will vary with the kind of water being tested. Suggested volumes are stated in Materials-Bacterial Sample.
2. Remove the protective rubber caps and plug the syringe valve and sampling tube into the field monitor. They will only fit in the proper opening of the field monitor.
3. Lower the sample tube into the measured volume of water. Draw back on the syringe plunger to pull the sample through the membrane filter. Several strokes of the syringe may be necessary to draw large volumes through. Invert the syringe, holding the monitor upright (membrane side up) to draw the last few drops through the filter.
4. Remove and discard the plastic sampling tube.
5. Carefully break the narrow tip of the medium ampule at the scored line and insert into the opening on the monitor over the filter surface.
6. Holding the medium ampule firmly in the hand and inserted in the monitor, break the top of the ampule at the scored line. Lift the ampule very slightly to allow medium to flow into the monitor.
7. A partial stroke of the syringe will draw the medium through the filter. Stop pulling on the syringe the instant the last few drops of medium disappear from the filter surface.
8. Replace the protective rubber caps and place each field monitor with membrane filter upside down in the incubator (35°C) for 20-24 hours.
9. After incubation remove cultures from incubator for counting.
10. Pry the field monitor apart. Be careful not to tear the membrane filter which occasionally may stick to the top part of the plastic container. This removal of the top portion of the field monitor makes it easier to see and count the bacterial colonies.

Examining Cultures

Place cultures under the counting light and adjust angle of light for best contrast of the golden-metallic-sheen colonies. Metallic-sheen is best seen by reflected light therefore the incident angle and reflection angle should be as nearly perpendicular to the specimen as possible. If light is not available use a 4x-magnifier and make as accurate a count as possible.

Count all yellow-sheen colonies using the 4x-magnifying lens. These golden-metallic-sheen colonies are coliform bacteria. Since coliforms are normally present in human feces as well as in that of other animals, their presence indicates that the water sample is not fit to drink. The other colonies which are red, pink, or grey, are not coliforms but some of the many hundreds of other kinds of bacteria which might be found in such a sample.



A. BEFORE STERILIZATION
B. AFTER STERILIZATION
C. INOCULATION OF BROTH WITH BACTERIA FROM FILTER
D. TUBE AFTER INOCULATION AND INCUBATION

USING FERMENTATION TO IDENTIFY BACTERIA
Figure 1

Follow Up

A. *How the Coliform Bacteria Are Identified*

When coliform bacteria are grown on a medium containing lactose sugar, the sugar breaks down into other organic chemical substances (aldehydes such as formaldehyde), and these decompose into gases and water. To identify this sugar decomposition use a chemical color test which can identify the presence of the aldehyde compounds. The German bacteriologist, Dr. Endo, made up a lactose medium to which he added the chemicals necessary, to give a golden-metallic-sheen to any bacterial colonies producing aldehyde compounds from this sugar. This medium is called Endo medium in honor of Dr. Endo. A modification of the medium, M-Endo MF, is used in this study and for identification of the coliform bacteria on the membrane filter.

The coliform bacteria will decompose lactose sugar into aldehydes and finally break down the aldehydes into gases and water. This process is fermentation. Another way to identify coliform bacteria is to develop a method for trapping these gas bubbles for visible evidence of gas production. This can be done by inserting a small test tube "upside-down" inside a larger tube of a lactose broth before sterilization of the medium. The resulting heat at sterilization temperatures forces the air out of the small inner test tube (fermentation tube) with replacement by the (liquid) lactose broth. When coliform bacteria are grown in such tubes for 24-48 hours at body temperature, some of the gas evolved by fermentation of the lactose sugar will be trapped in the inner tube giving visible evidence of gas production, see figure 1.

Observing the Fermentation Reaction of Various Bacterial Colony Types Growing on the Membrane Filter

To demonstrate that the coliform bacteria growing on the membrane filter will ferment lactose sugar with gas production, transfer some growth from a golden-sheen colony on the filter into a tube of phenol red lactose broth. Transfer of bacteria is usually done with a nichrome or platinum wire needle or loop held in the end of an insulated holder. To sterilize the wire, heat to a red glow in the flame and cool before transferring the colony to the phenol red lactose broth. Submerge the nichrome wire in the phenol red broth to insure mixing of the bacteria with the broth. After inoculation, incubate for 24-48 hours at 35°C. The coliform bacteria ferments the lactose sugar in the medium resulting in visible gas trapped in the fermentation tube. The phenol red dye will change the medium color from red to yellow indicating an increase in acidity (Figure 1D). By this same method check the reaction of the pink, red and grey colonies growing on the membrane filter. Do they produce gas? Does the phenol red lactose medium change color? Is it more alkaline or acid? (A deeper red color indicates an increased alkalinity.) In picking colonies for this experiment choose well separated ones to obtain pure cultures—not mixtures of different kinds. Why does the bacteriologist work with pure cultures when studying fermentations?

B. Further information on these organisms growing on the membrane filter can be obtained by preparing stained smears and studying their appearance under the oil immersion objective of a microscope. One of the most important stain procedures ever developed in bacteriology is known as the Gram stain, developed in 1884 by a Danish physician. The procedure divides the bacteria into two groups: those which are stained violet are Gram positive and the others are Gram negative. This information plus observation of the shape can be obtained on the same stained preparation. Coliforms are always Gram negative bacillus type.

Preparation of a Bacterial Smear:

(1) To prepare a slide of bacteria for staining, spread a drop of water on a microscope slide.

(2) Touch a sterile needle to a colony on the membrane filter or to the growth suspension in the phenol red lactose broth tubes. Then touch the needle to the drop of water on the slide. The suspension should just barely be visible to the eye. Too dense a preparation of bacteria (cloudy or chalky looking sediment) is difficult to stain evenly.

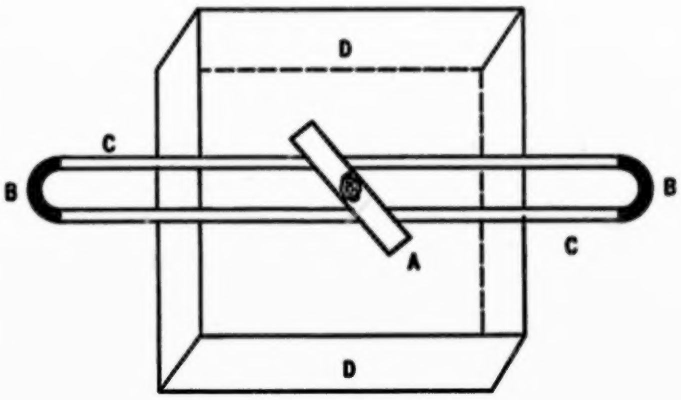
(3) Let the suspension air dry, then pass the slide quickly over a flame 2 or 3 times to heat-fix the bacteria to the glass slide.

Gram Stain Procedure:

1. Place slide on the rack (see figure 2). Stain one minute by completely covering the bacteria side of the slide with gentian violet solution.
2. Wash off excess dye in water. Replace slide on rack.
3. Repeat using Gram's iodine solution. Stain one minute.
4. Wash off excess iodine in water. Replace slide.
5. Decolorize in 95 per cent ethyl alcohol for about 30 seconds by pouring a little alcohol on the slide, agitating it, and washing off the excess alcohol in water. Replace slide on the rack.
6. Next, stain 30 seconds with safranin by completely covering the bacterial film on the glass slide.
7. Use water to wash off the excess safranin, dry, and examine under the oil immersion objective of a microscope. Are the sheen colonies Gram negative? Are they bacillus type? Repeat the demonstration using the red, pink and grey bacteria obtained on the membrane filter. Compare results.

Applications

The membrane filter has many applications in microbiology, nuclear science, general chemistry, pharmaceutical control, oceanography, industrial hygiene, tissue culture and medicine. The filter can be used to examine concentrations of bacteria, yeast, molds, protozoans, etc., from large volumes of water; to determine radioactive particles in waste; to clear microscopic particles from fluids; to collect particles for weight determinations; or to assay airborne hazards like fumes or smokes. At the Robert A. Taft Sanitary Engineering Center it is used as a research tool in the development of more rapid and sensitive indicators of bacterial pollution in water, milk, and foods. In addition, this technique is also employed at this research center in the monitoring of radio-active particulate fallout and other airborne hazards which are associated with air pollution.



A. MICROSCOPIC SLIDE TO BE STAINED
B. RUBBER TUBING
C. GLASS TUBING
D. CONTAINER OR SINK

RACK FOR STAINING
Figure 2

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Micro-Fungi in the Soil

C. LEROY HEINLEIN

Assistant Principal, Gamble Junior High School, Cincinnati, Ohio

and WILLIAM BRIDGE COOKE

Mycologist-in-Charge, Fungus Studies, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio

(FEBRUARY, 1958)

Background

The soil is a vast reservoir of chemicals which can be used by wild and cultivated plants as sources of nutrients for growth. As parts of plants or animals are returned to the soil in the form of litter, they are quickly or gradually decayed and their component parts returned to the soil as renewed material for the chemical warehouse. Agents of the decay process are many and varied. They include representatives of the protozoa, fungi, worms, insect larvae, crustaceans, and some plant roots.

Different species of these organisms have different food requirements so they attack different types of materials. Within a fragment of a leaf or twig are many different types of chemicals. One kind of mold will attack the simple sugars, another the more complex sugars and sugar-like compounds, another the cellulose, another the cutin and other substances on the surface of the leaf; still others will attack the more complicated compounds of which the skeleton of the leaf is composed. From the point of view of the fruit-bearing or spore-producing structure, two principal types of soil fungi are known—the micro-fungi or molds and the macro-fungi or mushrooms. It is with the former that this activity is concerned.

Fungi, in general, are classified as *Thallophyte* organisms. They are simple organisms without leaves, stems, or roots. These organisms may be one-celled or consist of groups of cells. The fruits of some fungi are microscopic; others are easily seen with the unaided eye. The fungi are non-green spore-producing saprobic or parasitic thallophytes numbering some 90,000 species including slime molds, blights, mildews, bread molds, lichens, yeasts, smuts, rusts, and various other fungi which are of extreme importance to man. Some are harmful, others are essential to human life. Fungi are all alike in that they depend on previously-formed organic matter for food, either directly or indirectly. They are constantly being investigated by research laboratories, like the Taft Sanitary Engineering Center, where extensive research is carried on to determine microbiological activity in man's environment.

Looking for fungi requires very little research. The air always contains fungus spores which will grow if they find any sources of food and moisture. Some fungi prefer the moist leaf mold of the woods and grow in profusion on the ground.

The fungi are worthy of study. They are easy to study because many are visible to the unaided eye and others can be seen with the low power of a microscope. Many can be grown in culture dishes throughout the year. They are safer to study than bacteria for only a few cause human disease and it is not likely that these will be picked up in an experiment of this type.

Problem

To determine the numbers and kinds of fungi in soils.

Materials

I. Samples of soil

Types of samples of soil are listed in the order of their appearance in a soil profile—soils in layers A, B, C, D, and E are all available in wooded areas; soils D and E are available from fields and gardens.

(A) litter layer . . . . . (composed of leaves and other plant materials which have fallen during the last year or more and are still recognizable)

(B) fermentation layer.......(composed of leaves and other plant materials which are decomposed so that they are hardly recognizable)

(C) humus layer........(composed of leaves and other plant materials which have decomposed so they are no longer recognizable)

(D) mineral soil at surface

(E) mineral soil three inches below the surface

II. Apparatus and equipment

- test tubes
- petri dishes
- distilled water
- hot water bath (if available)
- microscope
- cover slips #1
- graduate (25 ml)
- flasks
- spatula
- glass slides
- L-shaped nichrome wire needle
- pipettes (1 ml and 10 ml)
- agar (prepared dehydrated)
  1. Cooke Rose Bengal agar
  2. potato dextrose agar
- Amann mounting medium
- autoclave or pressure cooker
- Bunsen burner
- torsion balance or dietetic scale
- 6-oz or 100-ml dilution bottles

Procedure

Part I

Getting started:

1. Collect small samples of soil from all levels of the profile if they are available (collect and store in plastic containers; a school can purchase quantity amounts from drug supply houses); containers should be labelled to indicate soil layer, location, and date; information can also be entered on a card or in a notebook after the container has been numbered. If collecting is done on a field trip, the teacher should arrange for it with the owner or park superintendent beforehand.
2. From each sample collected, select three 15-ml portions of natural soil (to measure: use a 25-ml graduate, moderately packed to 15 ml); mark the samples for later identification.
3. Mix one of the 15-ml samples with 150 ml of distilled water.
4. Air-dry the remaining two 15-ml portions, being careful to keep them separate. Weigh each of these dried portions on a torsion balance, or its equivalent, and record the weight in grams to the nearest hundredth; mark the samples for later identification. The purpose of the dry sample is for translating the colonies per ml into colonies per gram following counting.

Preparing the sample in water:

5. Shake the 15-ml sample in 150 ml of water or mix in a blender or milk-shake mixer. If a blender or milk shaker is used, one minute of blending is sufficient; if done by hand, 5 minutes of shaking will suffice. Remove 5 ml of the blended soil and add to 45 ml of water or 1-part soil to 100-parts water. Shake mixture for a few seconds.
6. Repeat the mixing two more times, diluting the mixture by adding 5 ml of the first mixture of soil to 45 ml of distilled water, thus reducing the mixture to 1-part soil to 1000-parts water and finally adding 5 ml of the second mixing to 45 ml of distilled water, reducing the mixture to 1-part soil to 10,000-parts water. Mark each dilution for later identification.
7. The number of dilutions will depend on the sample; upper mineral soils, humus, and fermentation soils require more dilution. Proper dilution is determined by the trial and error method; however, when the colonies average 40-60 per plate the dilution is as near right as possible. Use the last dilution in the series of dilutions as your soil sample for testing. All samples will not require three dilutions, some samples will require more.

Preparing the agar:

8. Use dehydrated agar without antibiotics (Cooke Rose Bengal agar); this agar will eliminate some bacterial colonies but not all unless antibiotics are used.
9. Suspend proper amounts of the agar (see manual accompanying the agar; agars differ for companies which prepare them); 33 grams to a liter of water should be satisfactory.
10. Dissolve the agar in an Erlenmeyer flask of distilled water; heating may be required in a water bath (a pan of warm water large enough to hold the container of agar) depending on the rate of dissolving.
11. Place the dissolved agar in 6-oz or 100-ml dilution bottles, about ⅔ full, and autoclave for 15 minutes at 15 pounds of pressure. (Use a pressure cooker if an autoclave is not available.)

Preparing the culture:

12. Shake up the soil dilution suspension (prepared in steps 5 and 6).
13. Put one ml of soil suspension in a petri dish and pour in 15 ml of Cooke Rose Bengal agar before the agar has a chance to harden and when it is cool enough to handle safely. If the agar is too hot, it will kill the organisms present in the soil sample. (Prepare five such plates for each type of soil sample to assure accurate count.) Mark each plate for later identification.
14. Swirl petri dish gently on table top.
15. Cover the petri dish to (1) prevent contamination of the culture and (2) prevent spores from escaping into the room. Incubate right side up at room temperature for 5-7 days.
16. Repeat steps 12-15 for each type of soil and sample selected.
17. Observe and count the different colonies that develop. Do not uncover the plates. Autoclave

the plates to kill the spores before washing.

Part II

Preparing cultures for study:

18. Prepare, suspend, autoclave, and pour plates of potato dextrose agar following the directions given for Cooke Rose Bengal agar.
19. Using an L-shaped nichrome wire needle, carefully pick out a very small portion from one colony growing on the Cooke Rose Bengal agar plates; place this portion on the center of the petri dish containing the prepared potato dextrose agar.
20. Cover and allow to grow at room temperature until good colonies develop. After step 24 autoclave to sterilize and discard.

Identifying colonies by making permanent mounts from slide cultures:

21. Prepare a petri dish with 10-15 ml of potato dextrose agar; allow the agar to harden; divide it into 1-cm squares with a flame-sterilized scalpel (to flame sterilize a scalpel, dip it in 95% ethyl alcohol and burn off the alcohol).
22. Prepare petri dish as in Figure 1 with one or two slides on bent tubing support. Place sufficient glycerine or water in the dish to prevent drying out. In a second dry petri dish place a quantity of cover slips; autoclave both slides and cover slips.
23. Using a flame-sterilized spatula, place one block of the agar on the center of each slide in a petri dish.
24. Touch the nichrome wire needle to a colony obtained in steps 19 and 20 and wipe it around the edge of the agar of the slide.

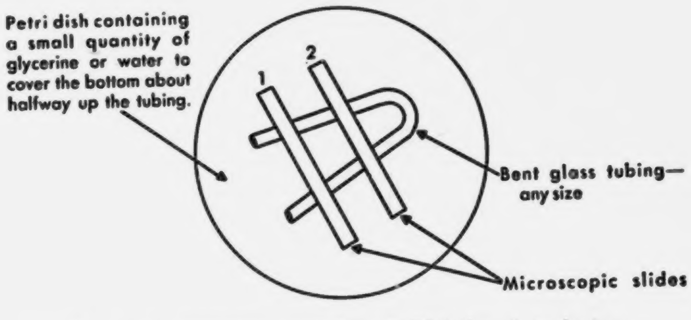
Petri dish containing a small quantity of glycerine or water to cover the bottom about halfway up the tubing.
1
2
Bent glass tubing—any size
Microscopic slides

Figure 1. Arrangement of Petri Dish for Autoclaving.

25. Place a sterile cover slip on the agar with a flame-sterilized forceps; mark for later identification; incubate at room temperature for 3-4 days; after 3 days cultures can be observed directly with a microscope by focusing through the cover slip.
26. Place a glass slide on the laboratory bench; place a drop of Amann's mounting medium in the center of the slide; remove the cover slip from the incubated slide as prepared in step 25 with a sterile forceps; place the cover glass with growth on the Amann's mounting medium on the slide; if culture is successful, ring the cover glass with clear nail polish to seal and mark for later identification.
27. Carefully remove the agar from the original slide obtained in step 25 and place a drop of Amann's medium on the slide where the agar had been and cover with a cover glass; seal edges. If the culture from the first slide is not successful, repeat steps 26 and 27 using the second incubated slide.
28. The colonies can be examined with a microscope and many identified as to genus by referring to H. L. Barnett's *Illustrated Genera of Imperfect Fungi,* Burgess Publishing Co., Minneapolis, Minn., 1955.

Follow-up

Several things may be done as follow-up including:

a) Counting the colonies to determine the number per ml of wet sample or per gram of air-dried sample.

   1. Procedure:
      a. Formula 1—To determine the number of colonies per ml of original wet sample

$$\frac{\text{total number of colonies for 5 plates of one sample}}{\text{number of plates}} \times \frac{\text{dilution}}{\text{15 ml}}$$

      b. Formula 2—To determine the number of colonies per gram of original air-dried sample

$$\frac{\text{Number of colonies per ml x 15 ml of the wet sample}}{\text{weight of the dry sample in g}}$$

      (the average weight of two 15-ml dry samples will approximate the weight of the soil in the original 15 ml of the wet sample)

   2. Example:

      Formula 1:

      Assume that there were 5 grams of soil per 15 ml, that 40 colonies were found on each of the five plates, and that the dilution was 1 part to 10,000. There was a total, therefore, of 200 colonies or an average of 40; multiplying 40 × 10,000 indicates a total of 400,000 colonies per 15 ml or 26666 + colonies per ml $\frac{(400{,}000)}{15}$; colonies can be reported to two significant digits or 27,000 colonies.

      Formula 2:

      If there were 5 grams of soil per 15 ml of wet sample, then 5 grams divided into 400,000 colonies gives 80,000 colonies per gram.

b) Make charts, graphs, and drawings of the fungi found.

c) Make a collection of permanent mounts for use in the classroom, or as a project for a science fair.

d) Exchange soil samples with pupils in different parts of the United States; develop colonies and permanent mounts.

e) Make drawings of the fungi identified with the microscope; obtain additional information about these fungi; use the information and sketches in making oral or written reports.

f) Examine soils from different parts of a locality; are similar fungi found at the same depths?

g) Diagram the soil profile where soil samples were collected; identify the soils and rocks shown; mount sketches of the fungi obtained and relate these sketches to the horizon on the diagram from which they were obtained.

h) Make a soil survey of the area where you live; chart, graph, or map your findings.

i) Collect, label, and display samples of soils available in the locality where you live.

j) Experiment with the effect of sterile soils on plant growth.

k) Make a complete study of a particular mold found in soil.

Applications

a) The Taft Sanitary Engineering Center has utilized the research with micro-fungi to:

1. Develop information concerning a reservoir of antibiotic-producing organisms, information about plant and animal disease fungi, and information about deterioration fungi.
2. Trace organisms in sewage from soil reservoirs.
3. Trace spores in the air; this is important in the study of allergies.
4. Trace sources of organisms important in deterioration of any kind of material (food, cloth, bedding, etc.).

b) Research with micro-fungi is important to agricultural sciences.

1. Determine that the numbers and types of fungi present in soil are a partial index of the microbiological activity in a soil and thus of some aspects of its potential fertility.
2. Develop information about animal and plant disease fungi.
3. Trace spores in the air as agents of plant disease.

c) Research with micro-fungi is important to military science.

1. Spores in the air.
2. Deterioration of material.

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Basic Steps to Teaching Bioassay of Water

RAYMOND L. HARTKER
Cincinnati Public Schools, Cincinnati, Ohio

CLARENCE M. TARZWELL
Chief, Aquatic Biology Section, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio

and CROSWELL HENDERSON
Chief, Biology Unit, Colorado River Basin Project, Salt Lake City, Utah

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PART I. VISUAL ANALYSES—THE MICROCOSM

Background

"Pure water" for civilian and industrial use as well as for the conservation of biological organisms is a problem facing each and every community in the United States.

To be aware of a problem and to be able to do something about its solution should be a challenge to every teacher of science. Too often, in our jet- and rocket-minded world, the problem of stimulating young minds is affixed to spectaculars such as sputniks and missiles rather than to the problems of everyday living. What must be remembered is that it takes water to make bread as well as water to make steel. Sanitary engineers insure our future health as well as our national defense.

The writers do not profess to be original in their context but only wish to coordinate the facts and ideas of many other authors of similar projects and processes.

A bioassay is an examination or analysis (assay) of life (bio). Ecology, the study of environment and its relationship to an organism, is a very necessary part of bioassay. A glossary of important terms is included to emphasize that a bioassay is relative to all conditions that exist, naturally or artificially, and that each condition has an effect that must be considered in the analysis of the total bioassay.

Tropism:	The response of a bio-organism to a *stimulus.*
Chemotropism:	The response of a bio-organism to *chemicals.*
Geotropism:	The response of a bio-organism to *gravity.*
Hydrotropism:	The response of a bio-organism to *water.*
Phototropism:	The response of a bio-organism to *light.*
Thermotropism:	The response of a bio-organism to *temperature.*

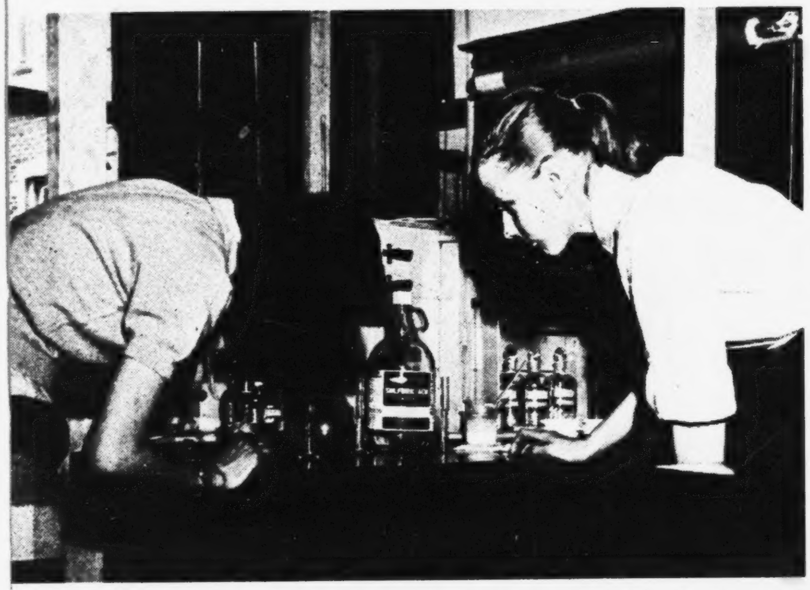
The microcosm, a little world in miniature, shall be used as the media for applying the scientific method of thinking to bring about visual analysis in this bioassay of water. A microcosm can arouse much student interest. It involves many questions which require hypotheses and experimentation for solutions; they also enable the student to go far beyond the mere recall of factual information—to think clearly and scientifically with the information acquired so that he can make generalizations that should enable him to apply these to new situations which may arise in his later experience.

Statement of Problem

The purpose of this experiment is to set up a microcosm in order to illustrate visually an ecological environment. This microcosm enables the student to apply the scientific method of problem solving to a changing balance in a marine environment, observing the results of such change and determining why the changes occurred.

Materials

A. A five-gallon bottle
B. Sand
C. Several aquatic plants *(vallisneria)*
D. Filamentous algae
E. Several small water snails



In the classroom: Measurement of reagent quantity calls for close attention from two Hughes High School students.

F. One small, healthy goldfish
G. A cork to fit the mouth of the bottle
H. Paraffin
I. Long hooked wire or tweezers

Procedure

1. Place two inches of sand in the bottom of the bottle.
2. Carefully anchor the *vallisneria* in the sand using long tweezers or a hooked wire.
3. Add water to a level about three-fifths of the way up the side of the bottle.
4. Add a small amount of filamentous algae, several small water snails, and the small goldfish.
5. Press the cork tightly into the neck of the bottle and cover with a heavy layer of melted paraffin.
6. Place the microcosm in the classroom.
7. As students evidence an interest, record their questions for follow-up.

Questions Asked by Students

How long can the fish live sealed in the bottle?
How does the fish obtain continued oxygen?
Why doesn't the fish starve?
Will the fish eat the snails?
What happens to the carbon dioxide?
Is air necessary for plants to remain alive?
If the water is not changed, will it become foul?
Do water forms need air to live or do they just breathe water?
Does temperature have any effect on the plant and water life?

Follow-up

Interest is a wonderful aid to learning. Once students are interested in the microcosm and the questions it poses, it is almost impossible to stop their wanting to find out the answers to their questions. The student awareness of the problem now existing sets the stage for the use of the scientific method of solution.

Divide the class into groups according to individual interests and abilities. Let each group choose the problem they would like to attack. These involve respiration, food, pollution, and ecology. Encourage pupils to post hypotheses, discuss them, and propose methods for trying them out. Some will be discarded as the group thinks them through. Others will be investigated through reading, experimentation involving observation, and the drawing of conclusions. Provide as many resources as you can for the students to use in testing their hypotheses. Let each group report their conclusions to the rest of the class.

Students of many biology classes had the experience of working with the microcosm. Pupil inquiries, related to an alteration of the original project, resulted in such questions as:

1. What would happen if the microcosm was placed in the sunlight or in the shade for a week's time? (Phototropism)
2. Does temperature affect the microcosm? (Thermotropism) .
3. What would happen if sewage or industrial type waste was put into the microcosm? (Chemotropism)
4. What if several goldfish were put into the bottle? (Ecology)

These questions led to students setting up additional microcosms to try out by experiment the effect of sunlight, darkness, temperature, pollutants, and additional water life on the balance of the microcosm. As these experiments are concluded, student committees should report their findings to the rest of the class so that their research can be shared by all.

Teacher and students soon found that their research led to many questions whose solution lay beyond the present realm of knowledge of the pupils. Sufficient interest was developed so that through teacher-pupil planning many desired to expand their knowledge beyond the visual bioassay and preparations were begun to consider such problems as:

A. How do you know or measure the amount of oxygen in the water? (Winkler process)
B. Does the chemistry of the water change with the amount of light or with the decaying of organic materials in the water? (Determination of *p*H)
C. How much industrial pollution does it require to kill fish? (Parts per million of solute toxic in water)

These questions are the basis for Part II—"Chemical Examination of Water," A and B, and Part III—"Bioassay of Chemicals in Water."

Some Other Learning Experiences

1. Visit the city water works to inquire as to the effect of industrial toxicants, sewage, and other wastes on our water supply.
2. Collect water from various ponds and streams. Place live guppies in these samples and see if they will support life.
3. Investigate problems of sewage disposal.
4. Invite persons in charge of water conservation in industry as guest speakers in the classroom. Ask them to discuss the following questions:
   a. What does industry do to prevent pollution in streams?
   b. Why does industry demand a good water supply before moving into an area?
   c. How are toxicants best removed?
   d. How long have we been aware of industrial wastes as a biological problem?
   e. What are some of the more harmful wastes?

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The authors would like to acknowledge the assistance of Dr. William A. Dreyer, University of Cincinnati, and Howard R. Thomas and Walter A. Warner, biology teachers, Hughes High School, Cincinnati.

PART II. CHEMICAL EXAMINATION OF WATER

A. Winkler Method, Unmodified for the Determination of Dissolved Oxygen in Water

Background

An adequate supply of dissolved oxygen, DO, is necessary for the life of fish and other aquatic organisms. The DO concentration at any one time indicates the septicity of the water or the satisfactory environmental condition for aquatic life. A series of measurements of DO may indicate the photosynthetic activity and biochemical oxygen demand.

In the determination of the dissolved oxygen in water, various ions and compounds may cause interference. In correcting for these interferences numerous modifications of methods have been proposed. These modifications are given in *Standard Methods for the Examination of Water, Sewage, and Industrial Wastes,* published by the American Public Health Association, Inc., 1790 Broadway, New York 19, New York. For field work and extensive aquarium analysis for DO, the teacher should be prepared to use modifications noted in the above reference. The Winkler method will be described below for the determination of dissolved oxygen in water.

The basic Winkler procedure entails the oxidation of manganous hydroxide in a highly alkaline solution. Upon acidification in the presence of an iodide, the manganic hydroxide dissolves and free iodine is liberated in an amount equivalent to the oxygen originally dissolved in the sample. The free iodine is titrated with a standard sodium thiosulfate solution, using starch as an internal indicator after most of the iodine has been reduced. The normality of the thiosulfate solution is adjusted so that one ml is equivalent to one mg/liter of dissolved oxygen when 200 ml of the original sample is titrated.

It should be noted that the water supply may contain interferences such as nitrates, ferrous and ferric iron, organic matter, sulfides, sulfites, polythionates, hypochlorites, suspended matter, and other oxidizing and reducing substances that may interfere with the Winkler test either by absorbing or reducing the liberated iodine or oxidizing the iodide to free the iodine.

Most natural waters, which support aquatic life, do not normally require a modification of the process for the determination of DO. The standard Winkler procedure is generally adequate. Modifications are usually necessary only when waters contain high concentrations of organic material or sulfite wastes.

Statement of the Problem

The purpose of this experiment is to show the student how the sanitary engineer, aquatic biologist, or allied professional person determines the amount of dissolved oxygen in streams, ponds, and lakes.

Materials

A. Several 250- or 300-ml capacity bottles with stoppers
B. Four pipettes, two ml, graduated in 1/10 ml or four eye droppers file-marked at one and two ml
C. Four 1000-ml flasks
D. One graduated burette, 50-ml capacity
E. One ring stand and burette holder
F. Crystalline manganous sulfate: $MnSO_4 \cdot 4H_2O$, $MnSO_4 \cdot 2H_2O$, or $MnSO_4 \cdot H_2O$.
G. Four or five liters of distilled water
H. Sodium hydroxide or potassium hydroxide; sodium iodide or potassium iodide; sulfuric acid, 36N; potassium bi-iodate or potassium dichromate; sodium thiosulfate.

Reagents

Make up the reagents according to directions.

Manganous sulfate solution: Dissolve 480 g $MnSO_4 \cdot 4H_2O$ or 400 g $MnSO_4 \cdot 2H_2O$ or 364 g $MnSO_4 \cdot H_2O$ in distilled water, filter, and dilute to one liter. When uncertainty exists regarding the amount of water of crystallization, a solution of equivalent strength may be obtained by adjusting the specific gravity of the solution to a value of 1.270 at 20 degrees C. The manganous sulfate solution should not liberate more than a trace of the iodine when added to an acidified solution of potassium iodide.

Alkaline iodide reagent: Dissolve 500 g NaOH or 700 g KOH, and 135 g NaI or 150 g KI, in distilled water and dilute to one liter. Potassium and sodium salts may be used interchangeably. The reagent should not give a color with starch solution when diluted and acidified.

Sulfuric acid, concentrated: The strength of this acid is about 36N. Hence, one ml is equivalent to about three ml of the alkaline-iodide reagent.

Starch solution: An emulsion of five to six g potato, arrowroot, or soluble starch is made in a mortar or beaker with a small quantity of distilled water. Pour this emulsion into one liter of boiling water, allow to boil a few minutes and settle over night. Use the clear supernatant. This solution may be preserved with 1.25 g salicylic acid per liter or by the addition of a few drops of toluene.

Standard potassium bi-iodate solution: A stock solution equivalent in strength to 0.1N thiosulfate solution contains 3.250 g $KIO_3 \cdot HIO_3$ per liter in accordance with the following reaction: 2 $KIO_3 \cdot HIO_3$ plus 20 KI plus 11 H_2SO_4 yields 11 K_2SO_4 plus 12 H_2O plus 12 I_2. The bi-iodate solution is equivalent to the 0.025N thiosulfate, contains 0.8124 g $KIO_3 \cdot HIO_3$ and may be prepared by diluting 250 ml of the stock solution to one liter.

Standard potassium dichromate solution: $K_2Cr_2O_7$ may be substituted for $KIO_3 \cdot HIO_3$. The $K_2Cr_2O_7$ should be previously dried at 103 degrees C for two hours. A solution equivalent to 0.025N sodium thiosulfate contains 1.226 g $K_2Cr_2O_7$ per liter.

Sodium thiosulfate stock solution, 1.N: Dissolve 248.2 g $Na_2S_2O_3 \cdot 5H_2O$ in boiled and cooled distilled water and dilute to one liter. Preserve by adding five ml of chloroform or one g NaOH per liter.

Standard sodium thiosulfate solution, 0.025N: Prepared by (a) diluting 25 ml sodium thiosulfate stock solution to a liter, or (b) dissolving 6.205 g $Na_2S_2O_3 \cdot 5H_2O$ in freshly boiled and cooled distilled water and diluting to one liter. Standard sodium thiosulfate solution may be preserved by adding five ml of chloroform or 0.4 g NaOH per liter.

Standardization with bi-iodate: Dissolve approximately two g potassium iodide, free from iodate, in an Erlenmeyer flask with 100 to 150 ml of distilled water, add ten ml of dilute H_2SO_4 (one part concentrated H_2SO_4 to nine parts of distilled water) followed by exactly 20 ml standard 0.025N bi-iodate solution. Dilute to 200 ml and titrate the liberated iodine with the thiosulfate solution, adding starch toward the end of the titration, when a pale straw color is reached. Exactly 20 ml of 0.025N thiosulfate should be required when the solutions under comparison are equal strength. It is convenient to adjust the solution to exactly 0.025N. One ml 0.025N thiosulfate is equivalent to 0.2 mg of oxygen.

Standardization with dichromate: Same as above except that 20 ml standard dichromate is used in place of the 0.025N bi-iodate. Place in the dark for five minutes, dilute to approximately 400 ml, and titrate with 0.025N thiosulfate.

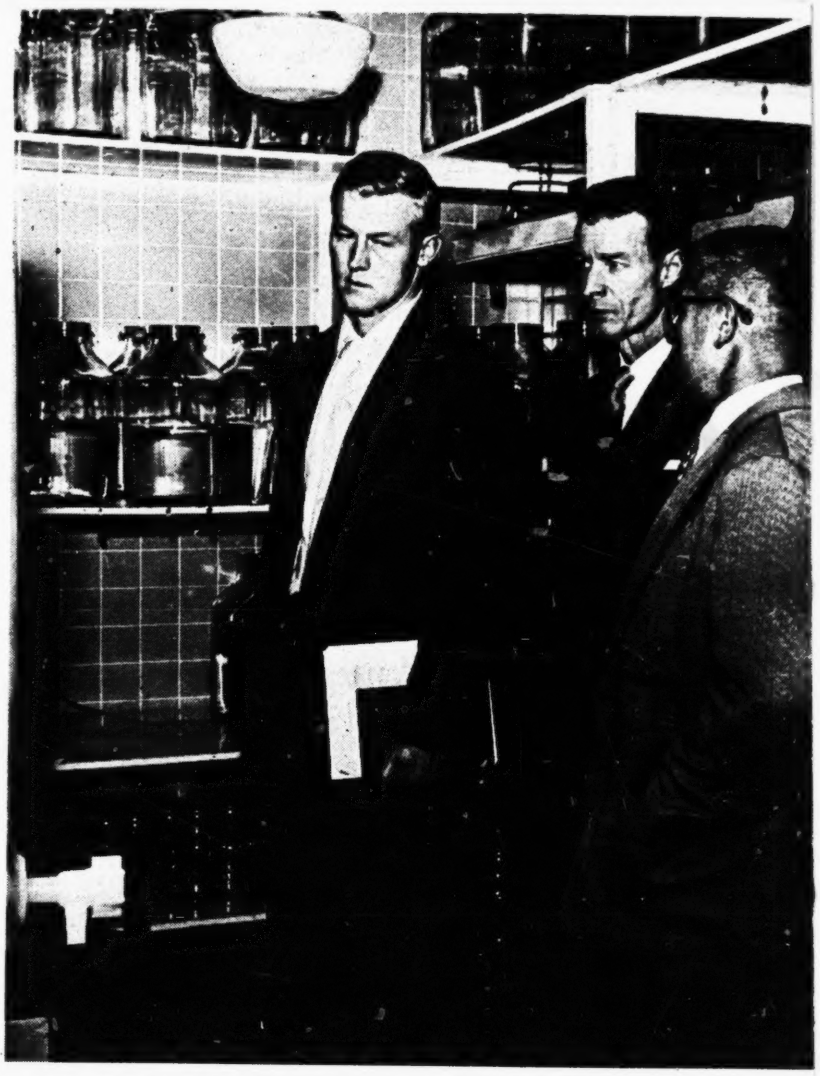
Procedure

Collection of Samples. Collect the samples in narrow-mouth glass stoppered bottles of 250- to 300-ml capacity. Special precautions are required to avoid entrainment or solution of the atmospheric oxygen. In sampling from a line under pressure, a glass or rubber tube attached to the tap should extend to the bottom of the bottle. Allow the bottle to overflow two or three times its volume and replace the stopper so that no air bubbles are entrained.

Samplers which permit collection of the dissolved oxygen, biochemical oxygen demand (BOD), and other samples from streams, ponds, or tanks of moderate depth are illustrated in the reference given in the background material. Water from depth samples taken in a one- to three-liter Kemmerer sampler is bled from the bottom through a tube extending to the bottom of a 250- to 300-ml dissolved oxygen bottle. In sampling from a reservoir at considerable depth a sampler provided with a valve release should be used. The temperature of the sampled water should be recorded to the nearest degree centigrade.

Preservation of Samples. There should be no delay in the determination of the dissolved oxygen of all the samples that contain an appreciable iodine demand or ferric iron. Preservation of samples for four to eight hours is accomplished by adding 0.7 ml conc. H_2SO_4 and one ml of two per cent sodium azide to the sample in the dissolved oxygen bottle. This will arrest the biological activity and maintain the dissolved oxygen if the bottle is stored at the temperature of collection or water sealed and kept at a temperature of ten to 20 degrees C. As soon as possible, complete preparation of the sample.

Preparation of Samples. To the sample as collected in the 250- to 300-ml bottle add two ml* $MnSO_4$ solution followed by two ml alkaline-iodide reagent well below the surface of the liquid, stopper with care to completely exclude air bubbles, and mix by inverting the bottle several times. When the precipitate settles leaving a clear supernatant above the manganese hydroxide floc, repeat the shaking a second time. With sea water a ten-minute period of contact with the precipitate will be required. When settling has produced at least 100 ml of clear supernatant, carefully remove the stopper and immediately add 2.0 ml conc. H_2SO_4 by allowing the acid to run down the neck of the bottle; restopper and mix by gentle inversion until the solution is complete. The iodine should be uniformly distributed throughout the bottle before decanting the amount needed for titration. This should correspond to 200 ml of original sample after correction for the loss of sample by displacement with the reagents has been made. Thus when a total of four ml, two ml each of the manganous sulfate and alkaline-iodide reagents, is added to a 300-ml bottle, the volume taken for titration should be:



Studying the Sanitary Engineering Center's water supply and water pollution program, Mr. Hartker inspects a fish toxicity experiment room. With him are the Center's director, Harry G. Hanson, and C. M. Tarzwell (right), chief of aquatic biology and one of the authors of this article.

$$200 \times \frac{300}{300-4} = 203 \text{ ml}$$

Titrate with 0.025N sodium thiosulfate to a pale straw color. Add one to two ml of freshly prepared starch solution and continue the titration to the first disappearance of the blue color. If the end point is overrun, the sample may be back titrated with 0.025N bi-iodate added drop-wise or by an additional measured volume of sample. Correction for the amount of bi-iodate or sample should be made. Subsequent recolorations due to the catalytic effect of nitrites or to the presence of traces of ferric salts which have not been complexed with fluoride should be disregarded.

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*The change in the volume of reagents is made because two ml of reagents insure better contact of reagents and sample with less agitation. It is still permissible to use one ml reagent quantities with 250-ml bottles.

Calculation

Since one ml of 0.025N $Na_2S_2O_3$ is equivalent to 0.2 mg oxygen, the number of ml of sodium thiosulfate used is equivalent to the mg/liter of dissolved oxygen if a volume equal to 200 ml of original sample is titrated.

In a classroom determination of DO, ten ml of sodium thiosulfate were used in the titration. Using the formula:

$$\frac{200 \times \text{ml of sodium thiosulfate}}{203}$$

and substituting: $\frac{200 \times 10}{203}$ = 9.85 mg/liter or 9.85 parts/million

Some Other Learning Experiences

1. Collect water samples from ponds, streams, and lakes and run a determination for dissolved oxygen. Compare.
2. Take water samples from your microcosms and run a determination for dissolved oxygen. Compare.
3. Invite an aquatic biologist to talk to the class.
4. Determine the effect of various pollutants upon the amount of dissolved oxygen in water.
5. If possible visit a government biological experimental station to study aquatic ecology.

Application of the Winkler Method

This method could be used to:

1. Determine the amount of oxygen resulting from the phototropic effects in aquaria placed in bright light as compared to aquaria placed in dim light.
2. Determine the amount of DO when many goldfish are placed in an aquaria as compared to just a few. (ecology and BOD)
3. Examine ponds and streams on field trips for DO and ecological purposes.
4. Check local drinking water supply.
5. Determine the amount of O_2 used to oxidize organic materials commonly disposed of through sewage. (closed and sealed bottle required)

Part II-B of the Chemical Examination of Water, an activity to follow, is designed to enable the student to study the pH and hardness of water.

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The Study of Organic Pollutants in Water

C. LEROY HEINLEIN

Assistant Principal, Gamble Junior High School, Cincinnati, Ohio

and F. M. MIDDLETON

Chief, Advanced Waste Treatment Research, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio

(MAY 1958)

Background

The quality of water must continually be maintained at a high level because water is a precious and limited resource. Many kinds of materials get into rivers and streams and pollute them. These materials sometimes cause the water to become foul and they interfere with many of the appropriate uses of water such as drinking and use for manufacturing. One very large group of materials can be classed as organic. Some organic pollutants are oils, detergents, phenol (sometimes called carbolic acid), and many hundreds of other chemicals. Other organic materials come from sewage and some are eroded from the soil.

Usually the pollutants are in the water in very low concentrations but even a teaspoonful of some materials in a million gallons of water can cause the water to taste or smell bad. It is necessary for chemists to recover these materials from water and to find out what they are by chemical or other tests. Because it is impossible to test for materials in such low concentrations, they must be concentrated so that enough material can be obtained for study.

The following experiments will help show how some of the materials are concentrated and recovered, and how the odor intensity of chemicals can be determined.

PART I. THE CARBON FILTER

Statement of Problem

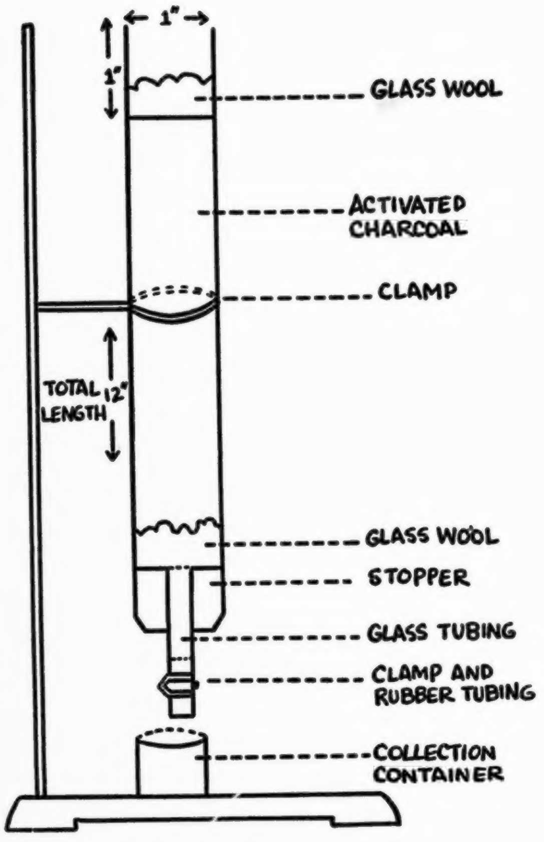
To demonstrate how organic materials can be collected and concentrated on activated charcoal.

Background

When wood or other organic material is heated to high temperatures in the absence of air, a charcoal, called activated carbon, is formed. This special charcoal has many tiny holes in it and acts like a sponge toward certain organic materials. In addition, it exerts a strong force (adsorption) that attracts the organic substances. When water containing organic material passes through a column of charcoal, the organic materials stay on the charcoal. In this way, the organic materials from several thousand gallons of water can be collected on a small amount of carbon. To recover the materials from the carbon for further study it is necessary to wash them off with an organic solvent such as chloroform. This is called extraction.

Materials

1. Granular charcoal—1 lb
   (This can be obtained from a store selling aquarium supplies. Better results are obtained by using a more highly activated charcoal. A possible source of activated charcoal—Cliff Char. 4 x 10 Carbon—is John P. Harris, Inc., 1791 Howard St., Chicago 26, Ill.)
2. A glass tube about 12" long and 1" in diameter
3. One 1-hole cork or rubber stopper to fit the end of the glass tube
   Insert a short piece of glass tubing into the cork. Put a short piece of rubber tubing over the end of the glass tubing and clamp this tube shut with a pinch or screw clamp.
4. Glass wool
5. Ringstand and clamp
6. Four 500-ml beakers or drinking glasses
7. Two test tubes
8. Three medicine droppers
9. The following solutions:
   - A. Make a blue solution by adding a very small amount (about 0.1 g) of methylene blue dye to 500 ml of water. Stir until thoroughly dissolved.
   - B. Add the amount of household detergent that you can get on the end of a pocketknife blade (about 0.1 g) to a liter of water. (Select a detergent that foams generously when shaken with water.)



Drawing 1. Carbon filter

C. A weak phenol solution (furnished by teacher). *Note to teacher:* Dissolve 200 mg of phenol in 1000 ml of distilled water.

D. Bicarbonate solution: Dissolve 0.5 g of baking soda in 1.0 l of distilled water.

E. Chlorine solution: Add 5 ml of laundry bleach (select one that contains chlorine) to 1.0 l of distilled water. This is the chlorine solution to use in the test. How is chlorine used at water treatment plants?

Caution: Do not spill the bleach on your clothes or hands. Wash your skin if any does get on it.

Procedure

A. Set up separate columns when filtering more than one solution or wash the carbon column thoroughly after each test by passing 400-500 ml of distilled water through the column.

B. Put the cork, containing the glass tubing, into the 12-in glass tube. Pack a small amount of glass wool or absorbent cotton over the stopper. Fill the tube with the charcoal, leaving about an inch of space at the top. Put some glass wool on top of the carbon to keep it from floating when water is added. (See Drawing 1)

C. Pass some distilled water through the carbon to wash off fine particles and to wet the carbon. Discard the water that comes through. Then clamp the tube at the bottom. Fill the carbon column with water and let stand, preferably for several hours. Drain before beginning the test.

D. Now slowly pour into the carbon column a glass full of the methylene-blue solution (9A) you prepared. Collect the liquid that comes out of the column. Adjust the clamp so that the material comes through the column by drops and not in a stream. Note what has happened to the color of the liquid.

E. Fill a test tube one-half full of the detergent solution you prepared. Hold your thumb over the mouth of the tube and shake it vigorously. Observe what happens. Select 100 ml of the original detergent solution (9B); pass it through the column. Collect some of the solution coming through the column in a test tube. Shake vigorously. What happens? What was removed? Compare with the

In a taste and odor detection demonstration, Lee Musgrave, SEC chemist, pours water containing dye through a small carbon filter. Waters containing detergents and phenols were poured through the other filters as described in this article.

The Robert A. Taft Sanitary Engineering Center is one of Cincinnati's architectural as well as scientific attractions.

original tube that was shaken. See if you can find out from doing this demonstration how detergents are made.

F. Place 200 ml of the phenol solution (9C) in a clean 500-ml Erlenmeyer flask. Smell it. Describe the odor. Now add 2 ml of the bicarbonate solution you prepared (9D) to the phenol solution. Next add 2 ml of the chlorine solution (9E) to the phenol solution. Mix well and let stand for ten minutes. Smell again. Describe the odor. Is it stronger than before? Phenol gets into water through the discharge of waste products from industry. When chlorine is added to the water at water plants, the material you have just made (chlorophenol) is formed and may cause the bad odor (the taste, you will quickly discover, is even worse) which you have observed.

G. The water plant can treat these odors in different ways. Try the following:

1. To 100 ml of the chlorophenol you have made, add 5 more ml of the chlorine solution. Mix and let stand for 30 minutes. Smell the solution. What has happened? (Excess chlorine acts to form a nonodorous compound.)
2. Now pass another 100 ml of the original chlorophenol solution through the carbon column and collect in a beaker the liquid coming through. Smell this liquid. What is the result? (This represents another type of treatment based on adsorption used by water plants to remove odorous materials.)
3. Carbon does not remove all organics from water. See if the filter will remove the color from
   (a) a cola drink
   (b) tea or coffee
   (c) water tinted with fruit coloring

PART II. ODOR THRESHOLDS

Statement of Problem

To demonstrate how to measure odors produced by minute quantities of odorous material in water.

Background

Very low concentrations of organic contaminants can cause taste and odor in water. To get information on how much odor is present, a threshold odor test can be run. The nose is the best—and the only way presently known to measure these odors. The noses of people differ as to how much material they can detect. This experiment will explain how to run an odor test. Pilot runs of this part of the experiment were made in the classes of Robert Anderson, science teacher; Woodward High School, Cincinnati, Ohio.

Precautions

Because very small amounts of odor are involved, special precautions will need to be observed. *The water used to dilute the samples has to be odor-free.* The best way to make odor-free water is to slowly pass tap water through a column of carbon like the one used in Part I. This takes out the chlorine and other odorous materials. The preparation room should be as free from odors as possible. Odor tests should not be run immediately after eating. Scented soaps or perfumes should not be used prior to running an odor test.

Materials

1. 12 pint Mason jars with metal lids
2. Carbon column (from Part I)
3. Sample of odorous material (vanilla)
4. Pipette—1 ml
5. Containers—liter jar and/or gallon storage containers

Procedure

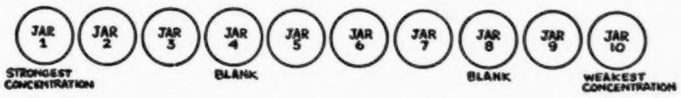
A. Prepare 3 or 4 gal of odor-free water by slowly passing tap water through the carbon column into *clean* gallon jugs. Smell the jugs and tops to be sure no odors exist.

B. Wash the pint jars and lids thoroughly. Smell each one to be sure no odors are left on the materials.

If odors remain rinse the jars well in odor-free water.

C. Add 1 ml of vanilla extract to 1.0 l of *odor-free water.* Mix well. This is the stock solution. How many times has the vanilla been diluted?

D. Now take 400 ml of the stock solution and pour half of it into one of the pint jars. Put a number 1 on this jar. Take the remaining 200 ml of stock solution and add 200 ml of odor-free water to it. Mix and pour half of this diluted mixture into another jar. Number this jar 2. Repeat the diluting procedure always using one-half of the amount in the previous step until you have prepared eight jars. These jars should be numbered 1, 2, 3, 5, 6, 7, 9, and 10 from the highest concentration to the lowest concentration. Prepare two other jars containing 200 ml each of odor-free water to represent blanks. Number these 4 and 8, and insert in sequence as shown in Drawing 2. These two jars of odor-free water represent blank controls in the test. Be careful to keep the jars from picking up odorous materials.



Drawing 2. Arrangement of jars for odor test

E. You are now ready to run the odor test. Have a student pick up jar No. 10. Be sure to keep the hands away from the neck of the jar. Shake the jar vigorously with the lid tightly closed, then remove the lid and see if the vanilla can be smelled. Bring the jar close to the nose but do not touch the nose with the jar. If the vanilla can be smelled in jar No. 10, make further dilutions as in Step D until the vanilla cannot be smelled. If the vanilla is not smelled in jar No. 10, try Nos. 9, 8, 7, and so on. Mark down a + if anything is smelled and a — if there is no odor.

JAR NO.	*OBSERVATION* (+ *or* —)
10	
9	
8	
7	
6	
5	
4	
3	
2	
1	

The point where the odor is first detected is called the ***threshold.*** Check the threshold of the students in the class. Does everyone have the same threshold? Chart the results.

F. Now calculate how many times the original vanilla was diluted to get the threshold. Here is a sample calculation: To make the stock solution, the vanilla was diluted 1000 times. The No. 1 jar contains this stock solution; the No. 2 jar is diluted by a factor of 2; the No. 3 jar by another factor of 2; the No. 4 jar is a blank; the No. 5 jar has another factor of 2; and so on. If a student's threshold was found on jar No. 5 in Drawing 2, the amount of total dilution would be:

> 1000 x 2 (jar 2) x 2 (jar 3) x 2 (jar 5) = 8000 or one part vanilla to 8000 parts water
>
> (To obtain your threshold multiply by a factor of 2 each time you progress to the next jar, remembering that the blank samples are not used in computing the dilution factor.)

G. Find thresholds of some other materials such as oil of peppermint, oil of wintergreen, or some other food flavoring.

Applications

You have seen that activated carbon can be used to concentrate organic materials from water. Once these materials are concentrated, they can be removed from the carbon by extraction with solvents such as chloroform and alcohol. The solvents are distilled, leaving a residue. This residue represents the organic contaminants that were in a large volume of water. These contaminants may have been present in only one part in one million, or even one billion, parts of the water but they can cause taste and odor or interfere with water treatment. It is important to know if such materials in water affect health.

Chemists at the Robert A. Taft Sanitary Engineering Center recover and study organic contaminants as follows:

1. They develop methods for determining what kind and how much of the various materials are present in water.
2. They try to determine what materials cause water to taste or smell bad.
3. They study other damage caused by these contaminants such as interference with water treatment or damage to aquatic life.
4. They try to determine whether such materials in water can be harmful to humans.
5. Using the information gained from such studies, scientists are better able to maintain and control the quality of water for the nation.

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Techniques in the Study of Fruit Flies

ISADORE HALPERN

Science Teacher, Erasmus Hall High School, Brooklyn, New York

(DECEMBER 1960)

In considering the subject of genetics, it is not uncommon for high school biology students to study the heredity of the fruit fly. Although they may use charts or even observe flies in bottles, how often do most students ever arrive at a close examination of these insects? How many have ever seen a fruit-fly egg or larva under the microscope? Moreover, how many have ever anesthetized flies for observation in the laboratory?

Such studies need not be relegated only to college genetics classes or assigned to the talented student as special project work. Through the use of techniques described here, it should be possible to include fruit-fly study as general laboratory procedure for all high school biology students.

Two limitations usually are present in the handling of flies. The first is the use of ether for anesthetization—a hazardous procedure for high school students. The second limitation is the students' lack of experience with observation and handling of fruit flies in various stages of development.

The first limitation is overcome by the use of a cooling technique for inactivating flies, instead of using ether or another anesthetic. Cooling is accomplished by placing a stoppered vial or bottle of flies in an upright position in a bowl of water with ice cubes. Within a minute, the flies will fall to the bottom of the vial. The process of inactivation may be hastened by tapping the vial.

If the flies are left for an additional twenty to thirty seconds, they may then be shaken out of the vial. They will, however, begin to move about quickly. To overcome this, they should be placed on top of a metal container filled with ice water. A round tin of the type used for ointment is suitable. If the surrounding air is humid, moisture may collect on the tin, but this may be removed with a cotton-tipped applicator. Flies will stay quietly on this surface for several minutes and may be examined in this position using a camel's hair brush, or the tin may be placed on the stage of a binocular microscope for observation. (See Figure 1.) The insects are then shaken into a paper cone and returned to their vial.

The second limitation is overcome by the preparation of breeding vials for close study. The technique employed here is to place a block of food on a slide which is then inserted into a vial. (See Figure 2 a and b.) The food is prepared in the standard way and poured into a Petri dish where it hardens into a cake, and the closed dish is stored in a refrigerator. When needed, blocks of food are cut approximately 1½ by ½ by ⅜ inches and placed on the slide. A drop of yeast mixture is added to the food to promote fermentation. The vials are stoppered with cotton plugs or plastic caps which have been perforated with pinholes. The flies are placed inside, the slide containing the food block is inserted quickly, and the vial is capped. Fertile flies will begin to lay eggs soon afterwards, and within twenty-four hours, larvae will begin to emerge from the eggs. Egg-laying may be observed through the vial with a hand lens. Students find it interesting to give the same group of flies repeated cooling treatments and to watch them return to activity without apparent ill effects. Thus the cooling technique has a distinct advantage over ether in experimentation of this type.

For microscopic study, the slide containing the food block is removed after placing the vial in ice water to inactivate the flies. The cap is removed and the slide is withdrawn from the vial and examined for eggs, larvae, or pupae. One must not forget to cap the vial to prevent the flies from escaping. The cooling technique should be repeated before replacing the slide.

When the block of food is under the microscope, the eggs, larvae, or pupae may be moved or transferred with a dissecting needle or camel's hair brush, whichever can be used conveniently so as not to cause injury to the specimens.

Advantages of Techniques

It is possible to perform laboratory work at school and to take these vials home for continued study. There are no dangers involved since ether is not used. A student may devote more time to observa-

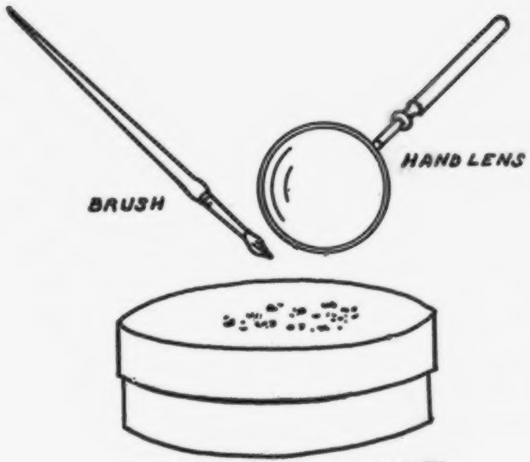


FIGURE 1.

tions this way, and his interest is not interrupted. Furthermore, members of the student's family often show interest in these home activities.

Facts About Fruit Flies

1. Female flies do not mate before they are 12 hours old. Therefore, in breeding experiments, newly emerged flies from pupa cases must be separated according to sex within this period.
2. They do not lay eggs before they are 48 hours old.
3. Larvae hatch from eggs in approximately 22 hours. The larva stage lasts for about 7 days.
4. The pupal stage lasts for a little more than 6 days.
5. The complete metamorphosis takes about 15 days.
6. Female flies hold the male sperms in their bodies and allow fertilization just before the eggs are laid.
7. Many eggs may be laid in an hour or two on the food block, if fermentation of the food is taking place.
8. The egg is about ½ mm long; the larva may grow to 4½ mm.

Preparation of a Breeding Vial

A convenient size vial is 3 inches long by ⅞ inches in diameter. Pieces of glass for slides should be cut about 2½ inches long by ¾ inches wide. The food block is cut to approximately 1½ inches long by ½ inches wide by ⅜ inches high. A drop of yeast suspension is added to the food block before use. About five flies should be placed in a vial to insure egg-laying. Motionless flies should never be shaken into a tube containing food because their wings may be caught. If a large number of offspring is desired, the parent flies should be transferred to several vials as soon as eggs are laid on a block of food.

Preparation of Food

The formula is given in parts per 100 g or cc. I have used the cornmeal-molasses mixture.

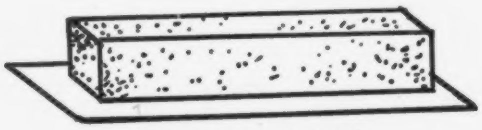
Water	74.3
Agar	1.5
Karo or Molasses	13.5
Cornmeal	10.0
"Tegosept M" *	0.7

The agar is dissolved by boiling in about two-thirds of the water; molasses or Karo is added and the mixture again brought to a boil. The cornmeal is mixed with the remaining one-third of cold water and poured into the boiling agar-molasses mixture. Add "Tegosept M" and cook for a few minutes with constant stirring. The medium should be thin enough to pour easily. Other mold preventives may be used. If breeding vials are prepared and used immediately, mold inhibitors may not be needed because the larva will feed on the molds before they spread. Should any molds develop, a bit of alcohol applied with a paint brush may quickly prevent their growth.

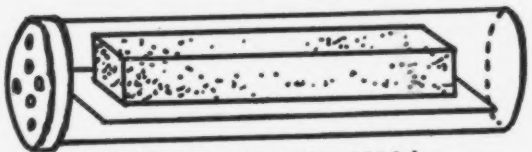
Suggestions

A. *Experiments on Behavior and Development.* Observations may be made of egg-laying, emergence of larvae from eggs after twenty-two hours, growth of larvae, feeding behavior of larvae and adult flies, pre-mating, and mating behavior.

Since these flies have a two-week life cycle, the complete metamorphosis of an insect may be studied in this period of time.



(a) FOOD BLOCK ON SLIDE



(b) BREEDING VIAL

FIGURE 2.

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* "Tegosept M" is a mold inhibitor (10 per cent alcohol) and may be obtained from Goldschmidt Chemical Corporation, 153 Waverly Place, New York 14, New York.

The responses of flies to stimuli may be studied by placing them in a glass tube about 12 inches long. (See Figure 3.) If both ends are corked, various foods and chemicals may be pinned on the inside of the corks to study reactions of the flies to stimuli.

The tube may also be held in various positions to determine the effect of gravity. Part of the tube may be covered to determine the effect of light.

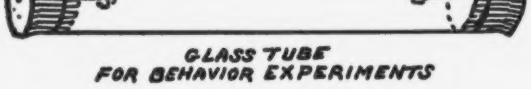
B. *Genetics Experiments.* The Mendelian Laws may be studied by using flies with dominant and recessive traits—normal wing which is dominant over vestigial wing, or normal body color which is dominant over ebony body color.

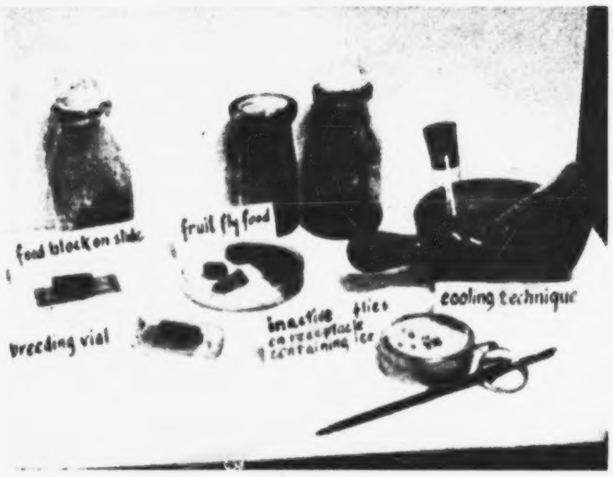
Sex-linked inheritance such as white eye color may be studied.

C. *Experiments Involving the Effects of Physical Factors on Development.*

1. Experiments may be tried in which the rate of metamorphosis is affected by changes in temperature. The temperature range study may vary between 10° C and 30° C or over. Students should build their own temperature-control incubators.
2. The effect of ultraviolet light on development could be studied. One might look for mutations or the behavior of flies under various kinds of light.
3. Flies might be exposed to various doses of X rays for determining mutation rate by subjecting them to strong radiation through the glass vials.
4. Radioactive isotopes such as Phosphorus 32 or Iodine 131 in quantities of not more than 10 micro-curies may be added to the fly food to determine whether mutations will occur. These isotopes are fairly safe because Phosphorus has a half life of 14.3 days, and Iodine has a half life of 8 days.
5. Variations in diet may be used to determine effects on growth and development.

FIGURE 3.





Materials used for fruit fly studies.

6. Flies may even be placed in high or low pressure chambers to determine whether there are any changes in development. Such experiments require the ingenuity of the student, and in this age of space travel these would be timely experiments.

These are but a few suggestions regarding the kind of experimental work that can be performed with fruit flies.

Conclusion

These techniques have been suggested so that students may combine school work with experimental work at home. The techniques are simple and safe, and the experimental materials are inexpensive and not bulky. They can be carried back and forth easily between home and school.

Since fruit flies are useful as experimental animals in various areas of biological study, this writer believes they should be employed more extensively in high school biology classes.

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PART C
Physical Sciences

Atomic and Molecular Models

GEORGE C. DOEPP
Instructor of Biology, Hyattsville High School, Hyattsville, Maryland

MILFORD H. DINKER, JR.
Instructor of Biology, Hyattsville High School, Hyattsville, Maryland

and **HOWARD B. OWENS**
Supervisor of Secondary Education,
Prince George's County Board of Education, Upper Marlboro, Maryland

(OCTOBER 1951)

In keeping with the dynamics of our times, a modern biology textbook used by the authors in teaching high school biology has included a chapter on chemistry and one on physics. An elementary knowledge of these physical sciences certainly contributes to a better understanding of many biological phenomena. However, in attempting to teach this newly included material, the usual supply of audio-visual aids was lacking. To remedy this situation, the authors devised a few pieces of equipment which they believe to be both economical and effective.

Atomic structure model. In order to show the structure of an atom, a model was constructed from the following materials.

> About six feet of wire similar in thickness to that generally used in coat hangers; one piece of one-half-inch dowelling, 18 inches long; one piece of scrap wood, approximately six inches by six inches by one inch; one dozen plastic balls, one-and-one-quarter inches in diameter (the authors found that ammunition for a child's jet gun was ideal*); one ping-pong ball; one roll of 26 gauge wire; one jar of red airplane dope; one jar of blue airplane dope.

A base for the model was prepared by drilling a one-half-inch hole through the center of the six-inch-square board and inserting the dowel into the hole. A one-half-inch hole was cut through the ping-pong ball so that it would fit snugly over the dowel, and it was pushed to the center of the dowel.

Three concentric rings were made by bending the heavy wire into circles. These rings were attached to the dowel by inserting them in shallow grooves made at 45-degree angles to the base. They were securely fastened by wrapping them at the points of insertion with the 26 gauge wire. To give the model depth, the rings were placed on different planes to each other. The ping-pong ball, which serves as the nucleus, was painted blue. The plastic balls, to be used on the rings as electrons, were painted red. Grooves were sawed half way through the balls. By squeezing the balls at right angles to the cut, they were readily attached like clothespins to the wire rings. Thus it was found to be a simple matter to rearrange a dozen different kinds of atoms without interrupting the class discussion.

Molecular structure models. The authors have experimented with molecular models and believe that for high school science a highly satisfactory model can be provided at low cost. This requires the following materials:

> Four dozen of the same type plastic balls mentioned above; 50 pieces of three-sixteenth-inch dowelling, two-and-one-half inches long; six pieces of rubber tubing, three inches long, with inside diameter to fit snugly over the ends of the dowels; 12 pieces of three-sixteenth-inch dowelling, one inch long, to fit inside the ends of the rubber tubing.

Holes were first drilled in the plastic balls. To symbolize hydrogen atoms, one hole was drilled in each of 15 plastic balls; to symbolize chlorine atoms, one hole was drilled in each of two balls; for oxygen, two holes were drilled more or less opposite one another; to represent any metal, three holes were drilled 120 degrees apart, on a great circle, in each of three balls. Next 12 carbon atoms were prepared by assuming that each ball was superimposed over an imaginary regular tetrahedron, with holes drilled at each of the vertices. Four plastic balls representing nitrogen, and one for phosphorus, had five holes drilled in each of them. Again it was assumed that each ball was superimposed over an imaginary regular tetrahedron, with four holes drilled at each of the vertices. The fifth hole was drilled by extending any one of the other four holes through to the opposite side of the plastic ball. Last of all, a ball with six holes was prepared symbolizing a sulfur atom, using a regular octahedron as a basis.

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* Manufactured by the Knickerbocker Plastic Company, Inc., Glendale, California.

The balls were painted different colors to distinguish different kinds of atoms, and the chemical symbols were added in a contrasting color.

The pieces of dowelling served as single bonds and for that reason should fit snugly into the holes in the balls. The rubber tubing was used as flexible double bonds. The dowelling in the ends of the tubing was fitted into the holes in the balls.

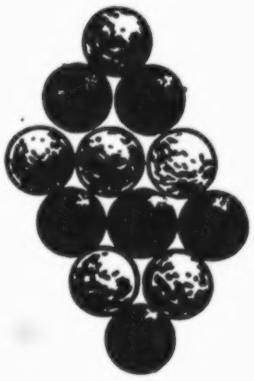
All of the above visual aids were constructed at a total cost of less than three dollars. While these models served their intended purposes for the authors, they may require some modifications for other situations.

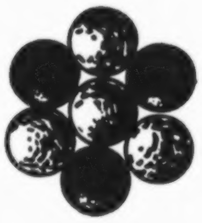
Atomic Structure Models

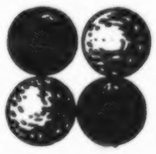
LOUIS PANUSH

Assistant Principal, MacKenzie High School, Detroit, Michigan

(SEPTEMBER 1952)

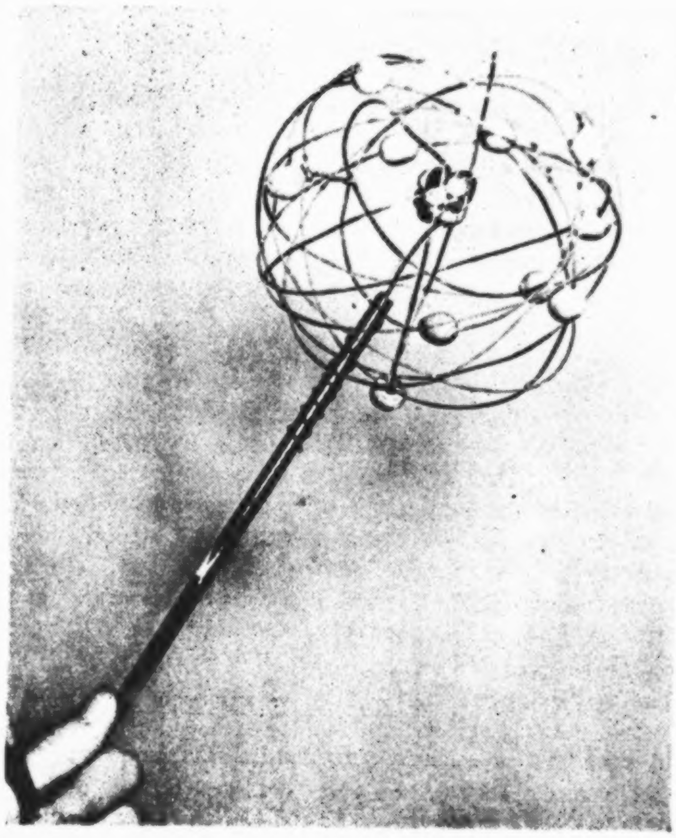






The October, 1951, issue of *The Science Teacher* (pp. 199-200) carried an article on the construction and use of atomic and molecular models. About two years ago, while I was teaching chemistry at Central High School, one of my chemistry students made for his term project structure models of the first ten elements in the periodic table, models which brought out more detailed information and better structural and spacial relationships in the atom. The accompanying photograph shows the details of structure. Beginning with hydrogen which had one proton in the nucleus (a small sphere of red clay) and one electron (a larger sphere of brown clay) in an orbit around it (made into a ring from thin brass wire), the student built up each successive atom with the required number of protons and neutrons (small spheres of blue clay, equal in size to the protons) in the nucleus and electrons in their orbits around it. The first shell (the 'M' shell) of each atom beyond helium consisted of two electrons, each in its own orbit and equidistant from the nucleus. The second ('N') shell was progressively built up to its maximum of eight electrons, each in its own orbit. Because of structure limitations, it was mechanically impossible to show electrons in energy sublevels; therefore, they were all equidistant from the nucleus. Each atom was mounted on its own dowel, and the ten structures were mounted on a base on which labels identified the elements, their atomic numbers and atomic weights. The individual structures were removable and could be passed around the class during discussion for individual inspection. This did not interrupt class discussion: it enhanced and dramatized it. As a visual aid in teaching the electron structure of the atom, there are few which will surpass it.

The idea for this project was taken from an article and colored drawings in *Life* magazine. It can be extended to show ionization (loss or gain of electrons), simple polar compounds, sharing of electrons in diatomic gases and in covalent compounds.



Determination of Half-Life

T. HANDLEY DIEHL
Instructor in Education, Miami University, Oxford, Ohio

and C. DON GEILKER
Research Associate, Department of Physics and Astronomy, Vanderbilt University, Nashville, Tennessee

(DECEMBER 1958)

THE Taft Sanitary Engineering Center has been concerned over the problem of air pollution as well as many other aspects of environmental health. In addition to the study and research programs at the center, an active training program is in progress for those who work in the field, and who will be directly associated with many of these problems. It is felt that the real meaning of half-life could not be understood by those in the training program without some direct experience. Short-lived isotopes are expensive and it is difficult to obtain them at a needed time. Mr. C. Don Geilker, who is involved with the training program, devised a method whereby the ever-present short-lived isotopes are used from the air for the experimentation-demonstration work done by the trainees. The apparatus runs approximately 4 hours prior to a laboratory period. In this way a sufficient quantity of short-lived radionuclides may be collected.

Several types of sampling equipment are available commercially. Some members of the science staff in the Cincinnati Public Schools have experimented with the use of a vacuum sweeper and filter paper to collect the samples with some degree of success.

Statement of the Problem

To acquaint the student with a laboratory method of determining the half-life of a radionuclide obtained from the air.

Equipment

Vacuum sweeper
Filter paper
Geiger-Muller tube and scaler
Lid from mayonnaise jar
Semi-log paper

Procedure

1. Place a filter paper in the hose of a vacuum sweeper so that the air coming in must be filtered before reaching the fan. (Sampling equipment may be obtained from companies listed.)
2. Draw air through the filter for approximately 4 hours. Best results will be obtained by sampling in a basement or other underground area with restricted ventilation.
3. Remove the filter paper from the sweeper and trim off the edge which did not collect any dirt. (Avoid touching the dirt on the paper.)
4. Place the sample thus collected in the lid of a mayonnaise jar and suspend over it either an end-window or side-window Geiger-Muller tube.
5. Record the counts per minute on a data sheet.
6. Repeat the count at 5 minute intervals.
7. Mark the horizontal axis of the semi-log graph paper in time units, beginning with the hour of preparation of the sample.
8. Plot the counts per minute, after subtracting background, on the log (vertical) axis of the graph paper, at the correct "clock time" of the count on the horizontal axis.
9. After six points have been plotted, connect with a straight line, and determine the half-life from the graph. (Fig. 1.)

(A background count for the instrument should be taken before running this experiment.)

Suggestions for Further Study

Dr. L. R. Setter of the Taft Sanitary Engineering Center has suggested placing cheese cloth in vertical and horizontal positions and permitting it to

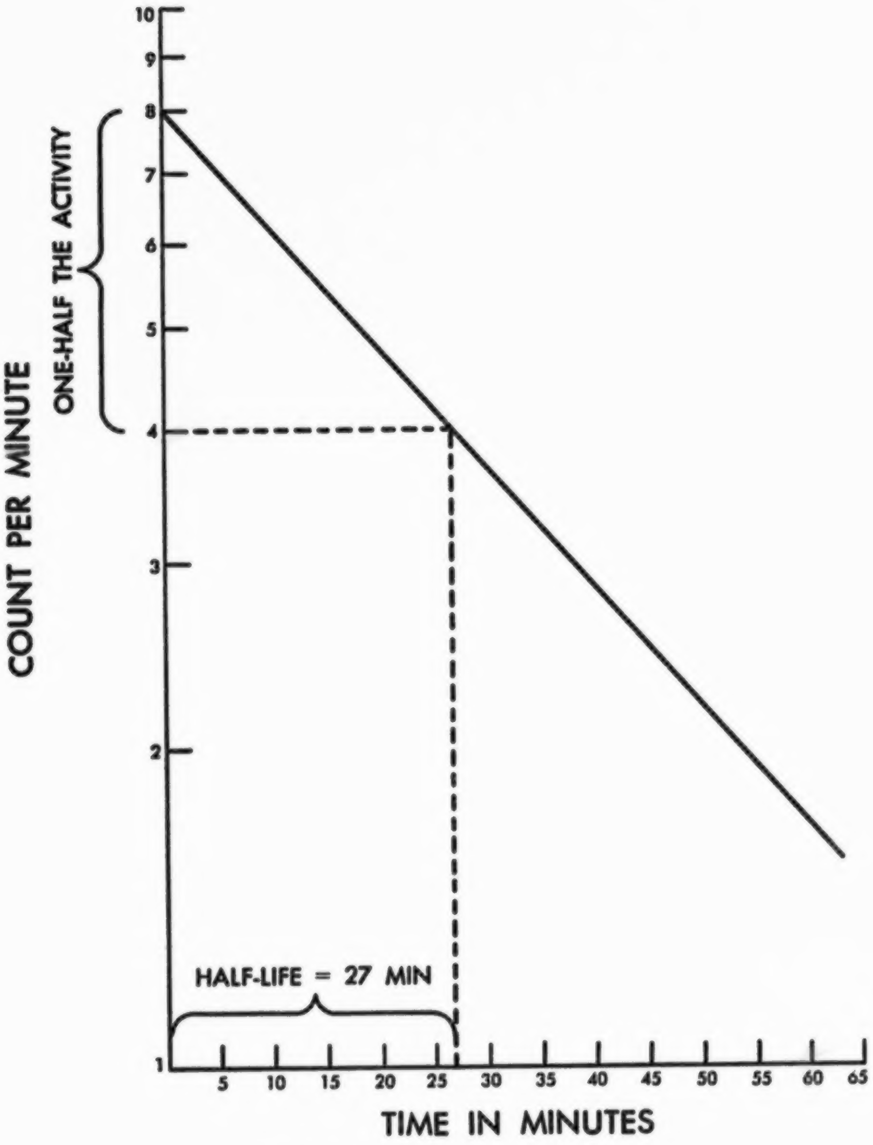


Figure 1. Half-Life Determination

collect radionuclides from the air. Dr. Setter thinks there may be detectable difference in the activity from collecting samples in the two positions with a preferential of the vertical position collecting the greater amount of activity. If this approach is attempted, the cheese cloth would have to be charred before being counted so that the activity would be more concentrated for recording.

The authors would like to acknowledge the assistance of Robert Anderson and Max Coyle, science teachers, Woodward High School. These teachers recently completed a course in "Atomic Radiation in Science" taught by Mr. T. Handley Diehl in connection with the University of Cincinnati program.

Sources of Sampling Equipment

Gast Manufacturing Corp., Benton Harbor, Michigan Air Samplers and other equipment

Ralph M. Parsons Co., 617 South Olive, Los Angeles, California Air Samplers and Pumps

Mine Safety Appliance Co., 201 N. Braddock, Pittsburgh, Pennsylvania Hand Operated "Samplair"

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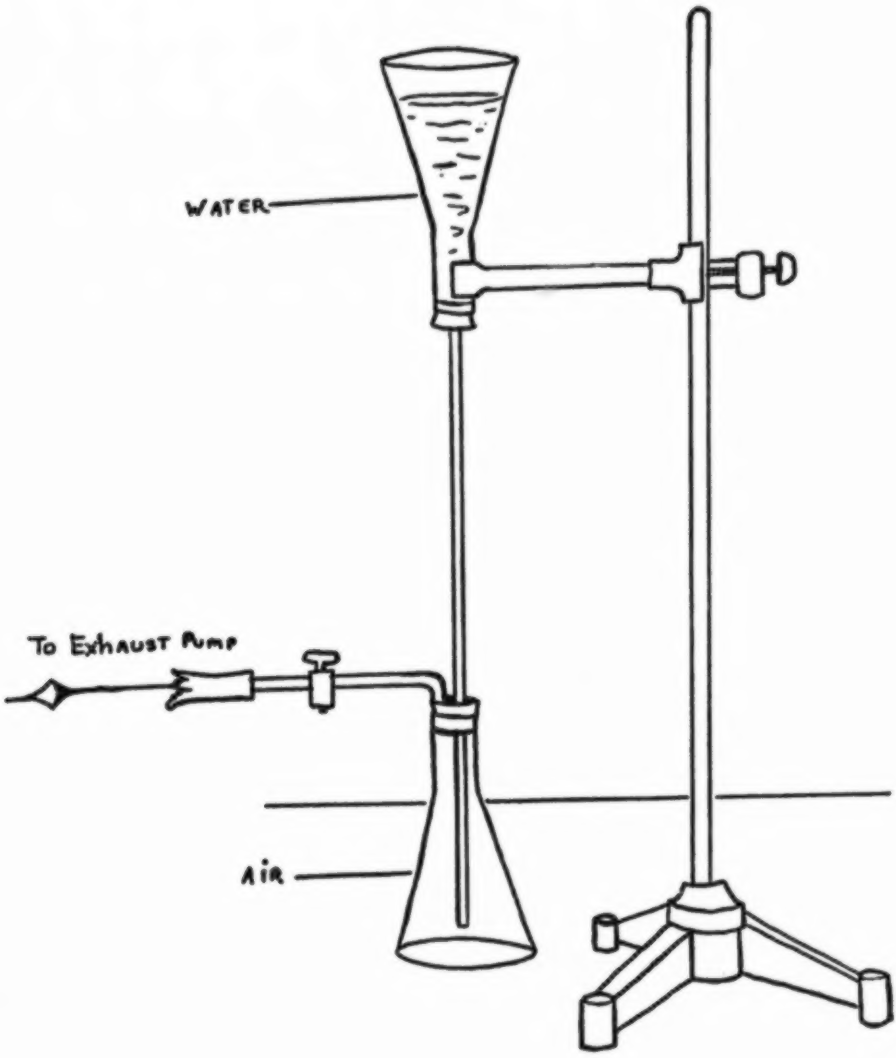
The Bacchus Experiment With Air Pressure

DONALD McCROSKEY

Science Student (1953), Central High School, Wadsworth, Ohio

(FEBRUARY 1953)



The simple apparatus I designed for this experiment, as shown in the illustration, has an upper flask which is filled with water. This is connected by means of a glass tube with a lower flask which is filled with air. Why does not the water in the upper flask move into the lower one?

With the use of an exhaust pump remove the air from the lower flask. (Caution: Include a filled calcium chloride drying tube in the line to prevent moisture from entering expensive, motor-driven pumps.) Why does the water in the upper flask now move into the lower one?

Finally, remove the core of the petcock thus opening the upper part of the lower flask to the air in the room. With this final arrangement why does the water rush from the lower to the upper flask?

Building a Wind Tunnel

CONRAD W. BATES

Head, Science Department, Chattanooga High School, Chattanooga, Tennessee

(OCTOBER 1951)

Preflight aeronautics was introduced as a course in our school in 1942. We have continued it as a science course and have obtained much equipment, including Link trainers, from war surplus. The early classes met in the biology laboratory and were without funds to purchase equipment even if it had been available. It was decided to build what equipment we could. All agreed that we would need some sort of a wind tunnel. Its construction, together with the building of scale model airfoils to be tested, became our first project.

A boy with a home workshop built two honeycomb sections each two feet square with openings one inch square. These were set up parallel to each other and one foot apart. The space between the sections was enclosed with a strip of cardboard. The honeycomb box thus formed was used to streamline the air.

Other boys plotted sections of Clark Y and NACA 23012 airfoils (the ones selected for study). From the drawings they prepared scale models with a chord length of about ten inches and a width of six inches.

Another boy loaned us a ventilator fan. Platform balances, ringstands, clamps, and pulleys were borrowed from the physics laboratory.

The equipment was set up as shown, and our wind tunnel was ready for operation.

Such equipment, though simple and somewhat inaccurate in performance, serves to stimulate interest in the subject and to demonstrate principles hard to visualize otherwise. With this equipment we are able to study:

1. The relation between lift and angle of attack.
2. The relation between drag and angle of attack.
3. The relation between drag or lift and airspeed.
4. Comparison of different airfoils as to lift and drag characteristics.

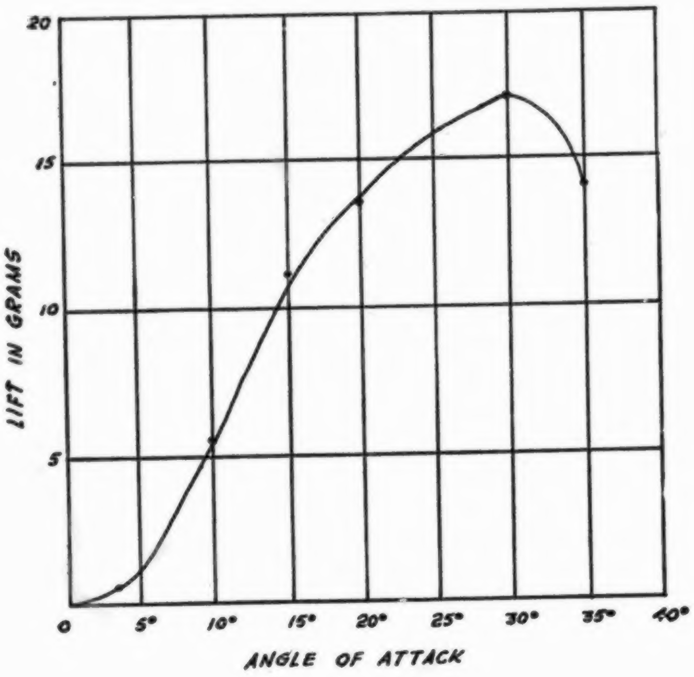
A copy of a student's experiment on lift follows.

Aerodynamics-Lift

Purpose: To determine the lift of an airfoil at various angles of attack.

Procedure: Improvised wind tunnel using electric fan; suspended Clark Y airfoil from ring stand; measured amount of lift in grams on balance. Angle of attack was then increased and lift measured. This was repeated until the peak of lift or burble point was determined.

Data:	Angle of Attack	Lift
	4°	0.3 g.
	10°	5.3 g.
	15°	12.3 g.
	20°	13.7 g.
	30°	16.9 g.
	35°	13.9 g.



A Jet Model That Works

E. JOE ALBERTSON, JR.

Science Teacher, Roslyn High School, Roslyn, New York

(DECEMBER 1950)

For 67 cents worth of common household materials a small working-model jet engine can be built which will effectively demonstrate the basic principles that underlie jet and rocket propulsion. Applicable to both general science and physics classes, this easy-to-build, simple-to-operate model is patterned after Hero's famous steam-jet engine of 2000 years ago.

Used as either a student project or teacher demonstration, it supplies an unique and fascinating approach to the study of Newton's Law of Reaction, and to classroom discussions of present-day achievements in jet-propelled aircraft, rocket development, and the intriguing prospect of interplanetary travel. This model will also lend itself nicely to a consideration of the history of jet development, which, contrary to popular belief, dates back to early times and was often an interesting blend of remarkable ingenuity and humorous efforts.

A simple, copper tank float provides the body for the jet engine. Copper tubing, one-quarter inch in diameter, cut into four equal lengths, approximately three inches long, should be bent in the middle, at right angles, to form the four separate nozzles for the engine. Attach these to the body in the following manner:

Punch four holes around the mid-section of the float at equal distances. These may then be enlarged to size by filing. The diameter should be just large enough to accomodate the copper tubing in a snug fit. Insert each nozzle and solder firmly in place, being careful to make a water-tight seal.

For nozzle heads, salvage four caps from the spouts of empty oil cans of the "3-in-1" variety. It will be found that these caps fit snugly into the opening of the ¼-inch nozzles. The soft metallic nature of the caps makes it easy to punch a tiny hole through the end with a straight pin. The nozzle heads may then be inserted and removed from the nozzles at will. The snug fit makes soldering unnecessary and adds greatly to ease of construction and operation. The tiny aperture develops a high gas pressure which will drive the jet at great speed.

The model is now complete except for the attachment of a swivel hook to allow the engine to revolve freely during operation. While many different fixtures can be used, an ordinary bronze pull-chain from a discarded lamp is quite suitable. Solder its bell-shape terminal to the top of the float. Then the engine will be free to revolve while firmly supported by the chain.

Operating the model is simple. Partially fill the float with water through an open nozzle. Then insert all the nozzle heads and apply heat to the bottom of the float.

As the water begins to boil, a fine spray of steam jetting out from each nozzle head will be noticed. Slowly the engine begins to rotate as exhaust-pressure builds up. Soon the model whirls at high speed, accompanied by the characteristic "trail" and sound of jetted steam.

Cost List

1 Tank float, copper	$0.47
¼″ Copper tubing (12-inch length)	0.15
Solder	0.05
4 Oil can caps, soft lead	0.00
Lamp pull-chain, bronze	0.00
Total Cost	$0.67

Squeeze Bottle Science

DOROTHY ALFKE

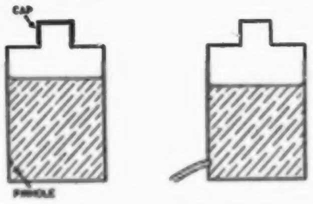
Associate Professor of Elementary Education,
The Pennsylvania State University, University Park, Pennsylvania

(OCTOBER 1954)

New packaging methods have placed in the hands of science teachers a clever piece of instructional equipment. We now find hand lotion, air deodorants, hair cosmetics, and many other materials sold in plastic squeeze bottles which can be rescued from discard for use in the classroom. Let's wash them with soap and water and use them.

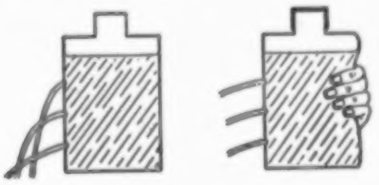
A. Remove the cap and submerge in water. Why doesn't the bottle fill with water? Squeeze the bottle under water. What comes out? What is the evidence for this answer? When the pressure on the bottle is released, what happens? What is the explanation?

B. Use a large needle or similar device to make a small hole near the bottom of one of the plastic bottles. Hold finger over the hole and fill with water.



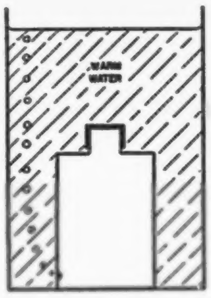
Place a cap on bottle. When finger is removed the water does not come out of the hole unless pressure is exerted on the bottle. How; explain? Remove the cap and the water spurts out of the hole. Explain. (This is an easy-to-prepare version of an old trick.)

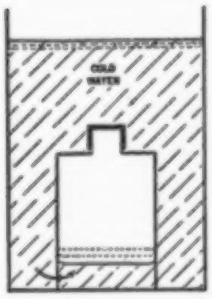
C. Make three or more pinholes, each at a different height, along the side of a squeeze bottle. Fill the bottle with water, leave the cap off, and allow the water to flow out of the holes. The difference in the streams of water at the various heights is an indication of the variations in pressure with depth in liquids.



If, however, we fill this bottle with water and screw the cap on, we can show that when pressure is applied to a confined liquid it is distributed equally in all directions. A gentle squeeze will produce jets of equal length. One might wish to make additional holes in the bottle for this demonstration.

D. A so-called "empty" squeeze bottle with a pinhole near the bottom and the cap screwed on can be used to illustrate heating effects of air masses. If this gadget, at room temperature, is placed in a jar of hot water, the heating effect of the hot water will be visible as bubbles of air are forced out of the hole and rise in the water. If this same "empty" bottle is placed in a container of ice water, the cooling effect of the cold water will be indicated by the flow of water into the bottle.





Other applications of science principles might occur to the reader. Certainly there is a place in science classes to discuss the purpose of the air spaces left in many containers of products marketed in squeeze bottles. There have been customer complaints about the partially empty bottles of such products offered for sale.

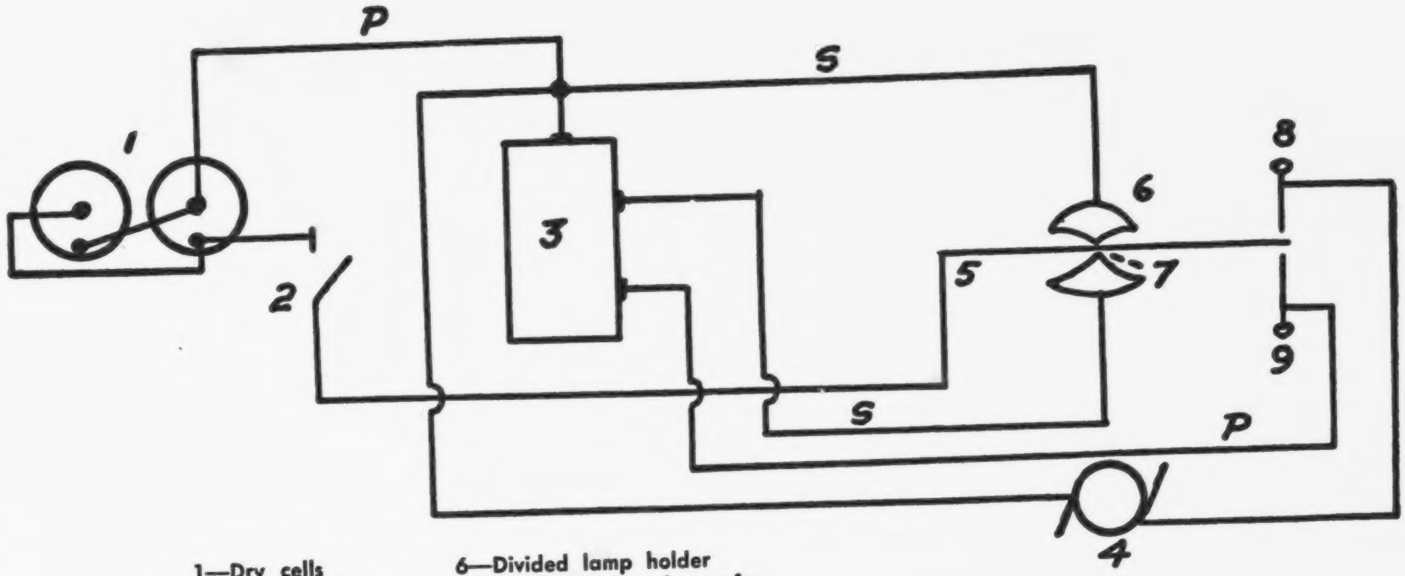
"Squeeze bottle science" could be used to stimulate interest in a topic to be studied, as a repetition learning experience, or as a novel method of testing for learning.

Thermostat Demonstrator

JENNINGS J. KING

General Science Teacher, McCormick Junior High School, Cheyenne, Wyoming

(MARCH 1954)



1—Dry cells
2—Knife switch
3—Model T Ford coil
4—Motor and fan
5—Bi-metallic strip
6—Divided lamp holder
7—Point of hot spark transfer
8—Contact screw for fan circuit
9—Contact screw for coil circuit
P—Primary circuit S—Secondary circuit

The "Jim Hosey" thermostat demonstrator intrigues students and shows the use of a bi-metallic strip as a switch in temperature control.

Jim Hosey, meteorologist with the U. S. Weather Bureau and former science teacher, gave me the rough plans for a thermostat demonstrator he had built. I turned the plans over to five of my ninth-grade students—Larry Marker, Kenneth Scribner, Nikki Breitweiser, Craig Stump, and Kenneth Largent—who adapted the plans to the equipment we had and built the gadget shown in the picture below. Construction details are shown in the drawing. After two years of hard use, including the display and operation at the Western Plains Science Fair, the device still works.

Two 1½-volt dry cells are connected in series to operate two electric circuits. A bi-metallic strip acts as a switch to control operation of both the fan motor and the model T Ford coil. When cold, the bi-metallic strip closes the coil circuit and a hot spark at (7) ignites the alcohol burner. The flame soon causes the bi-metallic strip to bend away, thus opening the coil circuit and stopping the flow of hot sparks to the wick. When the bi-metallic strip bends enough to make contact at (8) the fan operates and blows out the flame and permits the cooling of the bi-metallic strip so that the cycle may be repeated.

The 2-volt DC motor has the fan blades soldered to the armature shaft. The 8½-inch bi-metallic strip is made of 18-gauge galvanized iron and aluminum riveted together tightly—a contribution of our metal shop instructor, Mr. D. Frechette. The divided holder for the alcohol lamp is made of lightweight galvanized iron. One side hooks onto metal screw cap of alcohol lamp. The contact screws (8) and (9) may be adjusted so that the bi-metallic strip may have greater or less travel at the free end. The knife switch is used as the master switch.

An Automatic Sprinkler System Head

ALBERT F. GILMAN, JR.
Director of the Laboratory, Central YMCA Schools, Chicago, Illinois

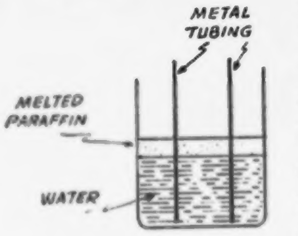
and ABRAHAM RASKIN
Professor of Physiology and Coordinator of the Sciences
Hunter College, New York City

(NOVEMBER 1951)

One of the difficulties encountered in teaching science is the standard demonstration which frequently fails to work properly. One demonstration in this category is the automatic sprinkler head model employing a shower head which has been covered with a layer of paraffin.

The writers have found that the apparatus diagrammed below is much more reliable than the standard demonstration.

To prepare the tubing, first pour a quarter-inch layer of melted paraffin over the surface of some hot water contained in a beaker. Then place the piece of metal tubing into the beaker (see diagram on the left), and allow the paraffin to cool and harden. The tubing is then withdrawn and the paraffin on the outside of the tubing scraped off with a knife.

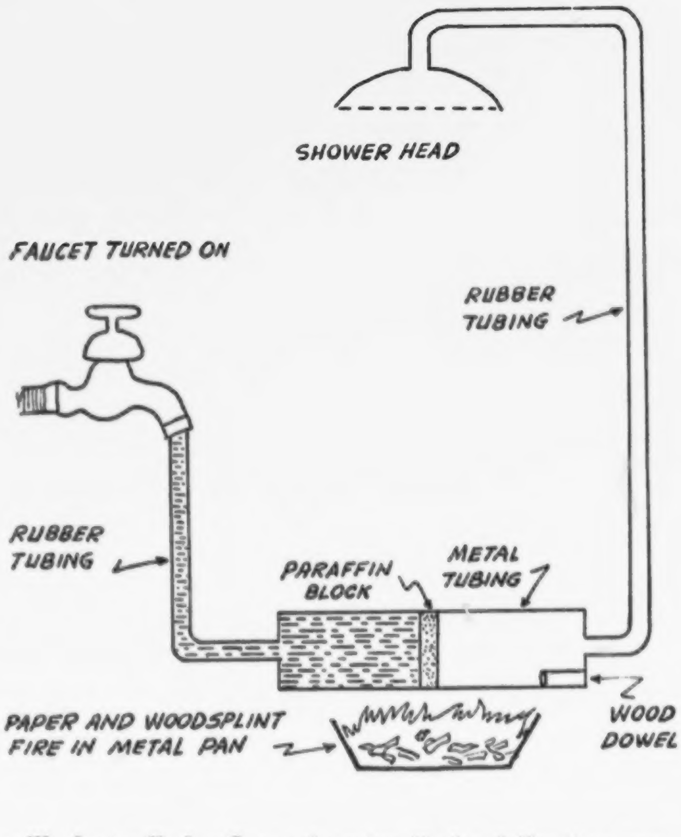


In the commercial automatic sprinkler systems installed in restaurants, department stores, laboratories, and other establishments, each orifice is covered with a copper disk which is held in place by a pair of sprung levers. The levers, in turn, are held in position by a low-melting-point alloy composed of cadmium, bismuth, and lead. The alloy can be varied in composition so that it will melt at any of a wide range of temperatures, say, 165 degrees F. to 360 degrees F. When the heat of a fire melts the alloy, the levers open and pull the copper disk away from the orifice, releasing the flow of water.

The orifices are not plugged directly with the low-melting-point alloy because it has been found that the low temperature of the water at the orifice may be sufficient to resolidify the alloy and close off the orifices.

The demonstration described is similar to the commercial apparatus in that the low-melting-point material is not used to fill the openings from which the water will issue, but serves as a kind of fuse.

In the demonstration there is little danger that the paraffin will resolidify, in the heated metal tube or elsewhere in the system, into a form which will shut off the flow of water if the following precaution is taken. Secure a small piece of glass tubing or wood dowel near the point where the metal tubing joins the glass tubing leading to the shower head. This will have the effect of tilting the melted piece of paraffin and will allow the water to flow by it into the rubber tubing and to the head.



To Demonstrate the Hot Water Heater

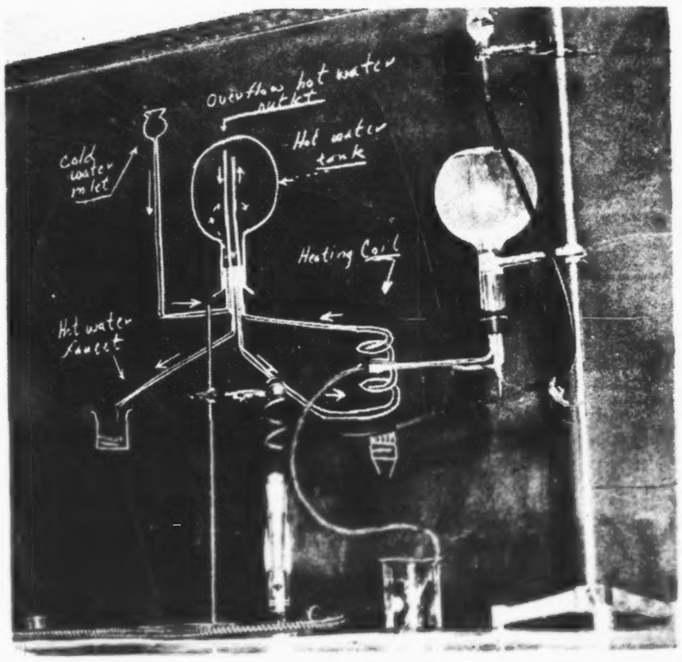
ROBERT S. JAQUISS
Seward Public Schools, Seward, Nebraska

(APRIL 1955)

I have been distressed in the past by my own inability to demonstrate adequately to my general science class the workings of a hot water heater. I found the diagrams given in the textbook and the other references that I made use of inadequate. One called for the use of a glass tube that was to be the "heating coil." I found that with very little heat this formed bubbles inside the glass and the uneven distribution of heat caused the glass to break. I did substitute a piece of copper tubing for the coil, but of course one cannot see through the copper.

This year when the problem again arose, I set the wheels into motion and came up with what I think is a fairly good answer to the problem.

The materials needed are: a length of copper tubing bent into a coil similar to the coil of an old-fashioned water heater, a four-hole stopper made by boring two more holes in a two-hole stopper (this was done very easily by the shop instructor on the drill press—be sure to use a large enough drill), a 500-ml flask, two right-angle bends of glass tubing with the long end long enough to reach the bottom of the flask when inserted in the stopper, two right-angle bends with ends long enough to reach just through the stopper, several lengths of rubber tubing, broken-stemmed thistle tube, beaker, and pinch cock.



This apparatus is assembled as shown in the accompanying illustration. The glass tubing makes it possible to watch the progress of the water as it moves. Coloring the water is not too effective as the color soon disperses, but a small amount of fine sawdust (such as found in a box of chalk) will soon soak up and be carried about by the movement of the water. Because of the sawdust, the cold water tubes should not stick through the stopper any farther than just flush with the surface. The hot water tube from the heater coil is placed so that it will not be quite as high as the hot water outlet from the "tank." This will assure a water-filled circuit. The hot water will run only when the system is full. The flow is controlled by how much cold water is let into the cold water inlet. If the water level in the tank were allowed to fall below the hot water outlet from the heater coil, the delicate balance which makes the water heater work may be upset. When the coil is heated, water may spurt from the upper end in an undesirable fashion.

I found that this seemed to answer all questions. The movements were easily observed by the class.

Methods of Measuring Humidity

DONALD R. McMASTERS
Principal, East High School, Green Bay, Wisconsin

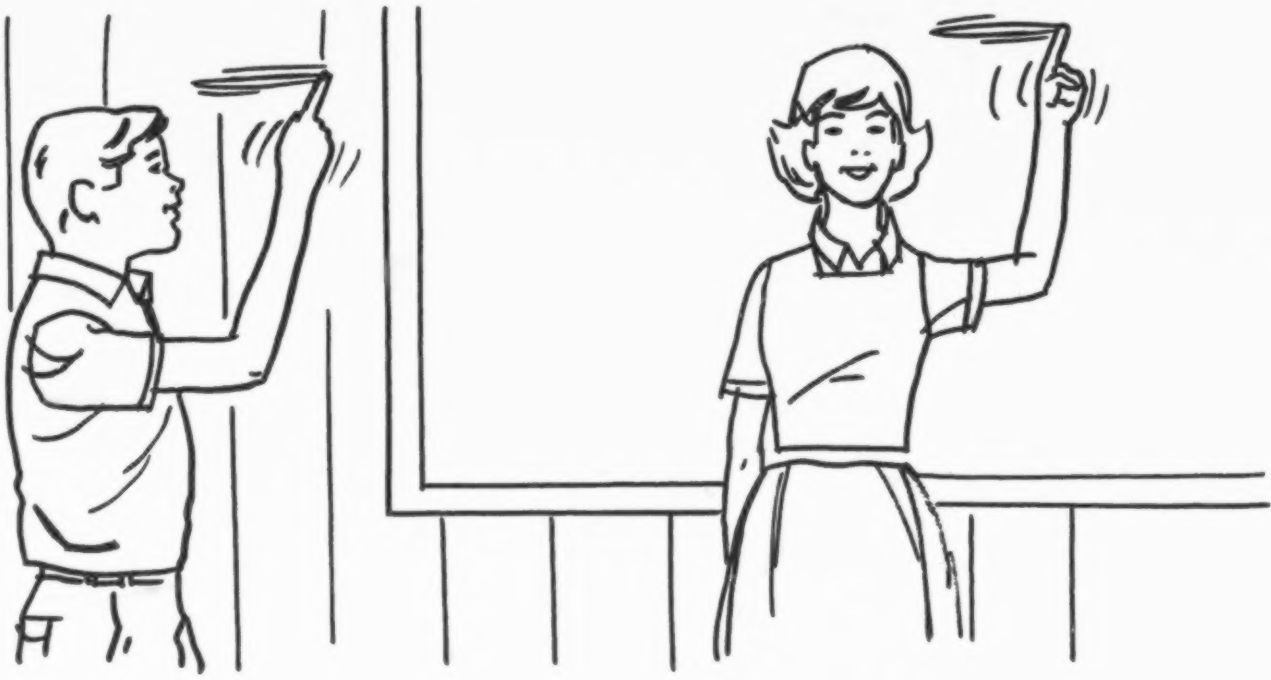
(DECEMBER 1951)

Most students today realize the importance of air conditioning and the need for proper humidity control. Many wet and dry bulb thermometer arrangements are available with which to measure relative humidity. Students easily learn how to read these instruments, but too few understand how they actually operate. A simple demonstration in which the entire class can participate can be used to overcome this objection.

Ask the class to move the right and left hands, with the forefingers extended, through a small arc. Do this first with both forefingers dry and then repeat the experiment with one forefinger dry and the other dampened with water. Each member of the class will note the difference in feeling in the second instance and the similarity in the first. (One or two students, however, may surprise the instructor by reporting a sort of road block in the blood supply to one or the other of the dry fingers and thus experience a mental temperature differential.)

All students will quickly note the similarity between the wet and dry fingers and the wet and dry bulb thermometers of the psychrometers or other hygrometers. These students then realize that the rapidity of evaporation from the wet finger might be used as a crude method by which to measure the amount of atmospheric humidity. Invariably class discussion brings out the fact that there would be less difference in feeling if the wet and dry fingers were waved in air heavily laden with moisture whereas the temperature difference would be greater and more noticeable at the other extreme. Air capacity, the temperature factor, and other items pertinent to humidity will also spring from the discussion.

This simple demonstration should prove successful in making students understand that the difference in the temperature of wet and dry bulb thermometers, when compared to air capacity, gives a definite measurement of relative humidity. Students therefore gain a deeper and more lasting appreciation of this entire problem.



Experiences With Light

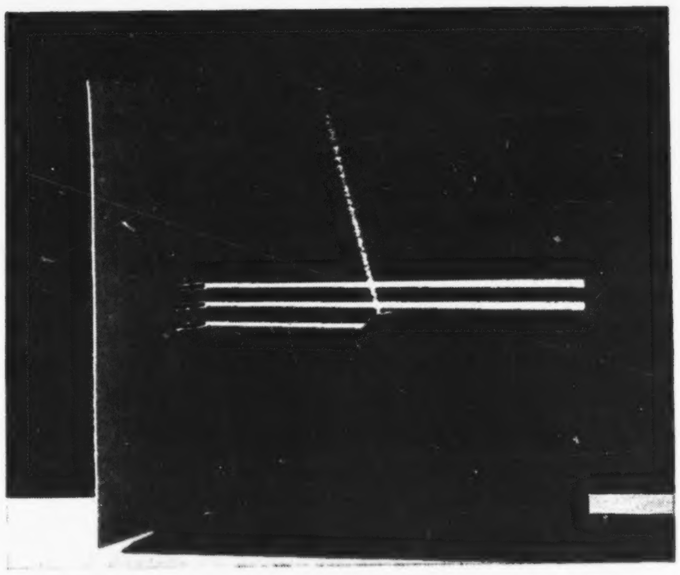
ALEXANDER STULER
Superintendent of a "Landkreis," Nördlingen, Germany

(FEBRUARY 1953)

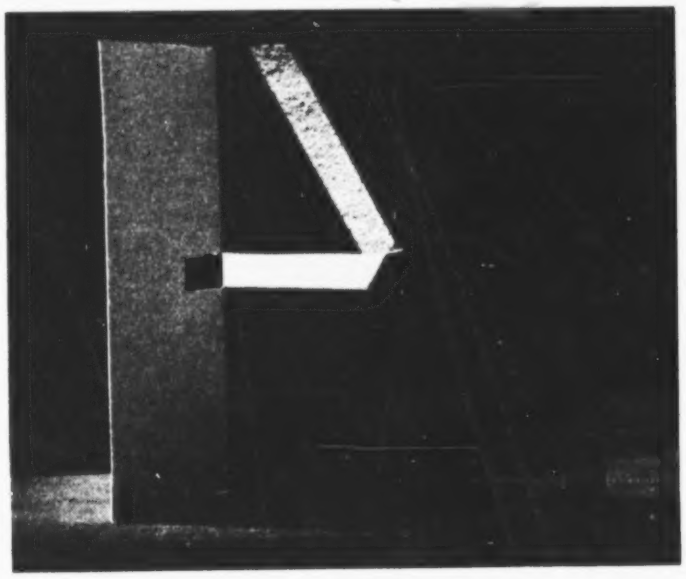
All you need is some cardboard, a dimestore mirror of the rectangular sort, two lenses of suitable focal length (about four inches, "+" and "—"), a prism, and a slide projector.

The slide projector will provide the light needed for the experiments. Six feet or so from the projector you place the cardboard. The cardboard is bent to a right angle and has a slit in its smaller front side, say, two inches long and one inch high. You turn the cardboard screen in a manner so that light entering through the slit shows its way along the inside screen. Then you bring the mirror into the course of the light beam. The mirror will reflect the light, forcing it into another direction. The new way of the beam, depending on the angle between the incoming light and the mirror, will show on the inside of the cardboard.

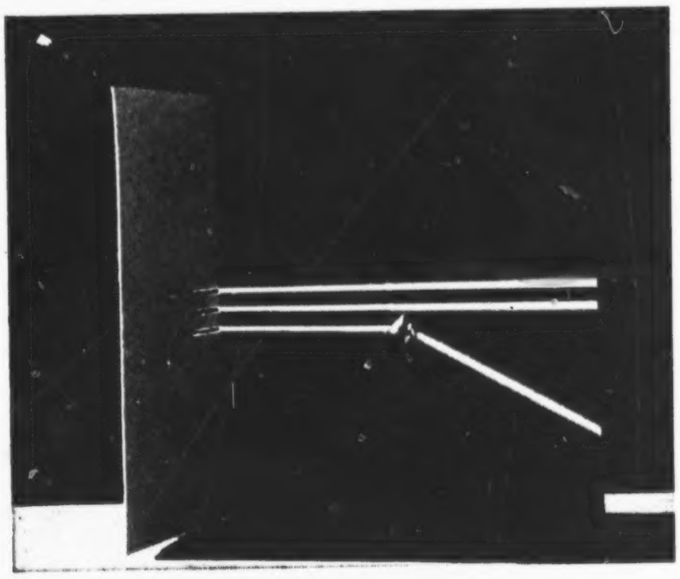
In the same manner you enter the prism into the beam and the light will be refracted, partly or en-



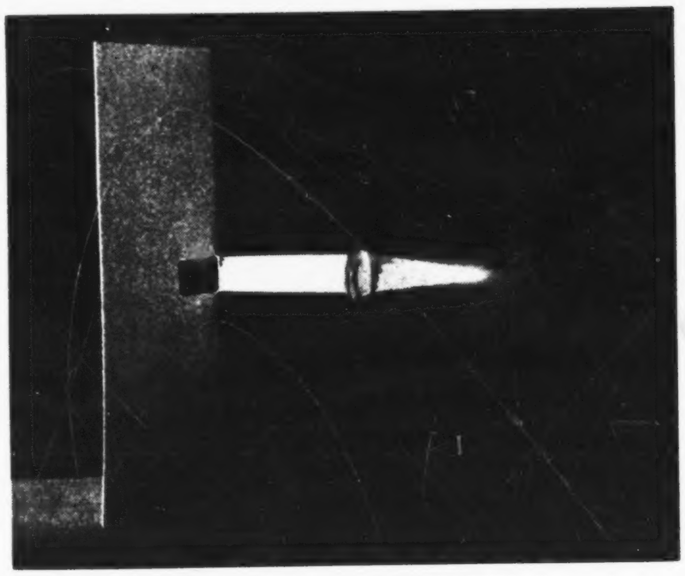
Reflection of light by a plane mirror, demonstrated with a cardboard with three slits.



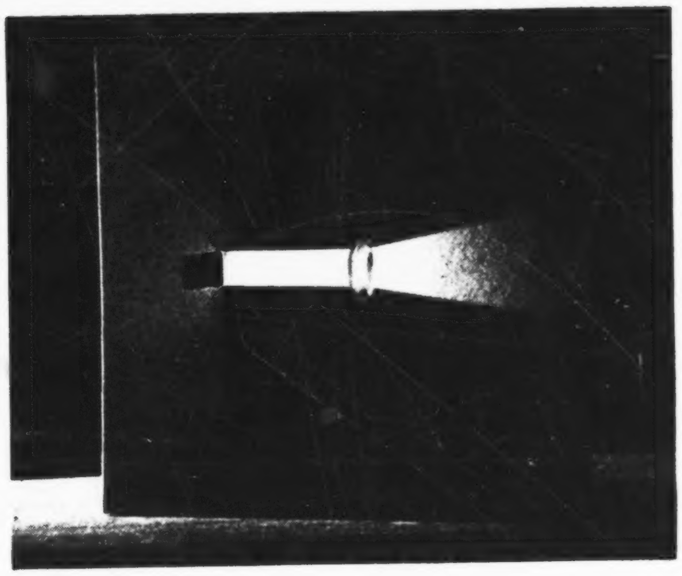
Reflection of light by a plane mirror.



Refraction of light by a prism.



How a convex lens converges light rays.



How a concave lens diverges light rays.

tirely according to how far the prism is thrust into the beam. If you turn the prism about its axis, differing angles will cause different grades of refraction.

For showing the way of light behind lenses, you are advised to use cardboard with suitable slits in the back of the screen in order to give room for the lenses. You can show then how light is either focused or diverted behind (beyond) the lens, depending on what sort of lens—convex or concave—is used.

In the place of a single broad slit you may use three or even five slits in front of the cardboard, especially if you would like to demonstrate that different zones of the lenses show different powers of refraction. In any case, one slit or more, the simple cardboard will tell more about the behavior of light than a long verbal lecture and will tell it more convincingly.

How to Make a Carbon Microphone

CHARLES F. BECK

Chairman, Science Department, Bristol Junior-Senior High School, Bristol, Pennsylvania

(MARCH 1954)

In the teaching of units on sound in various science courses, the telephone speaker for voice transmission is of general interest. Its main parts are the diaphragm and carbon granule box. The carbon granule box in the electrical circuit changes the physical energy of the human voice into electrical energy for transmission. When radio telephones were first developed, the adapted telephone speaker was the first microphone.

You may provide your own public address system at small cost. There is not much more needed than a radio set that is operating and one of the old stand-up type of telephone speakers. These are easily procured from your local telephone company as they are being discarded in place of the modern type French dial phone.

The mouthpiece with the carbon granule box is removed from the telephone stand by taking out the four screws that hold it. Two connections will be seen on the back of the granule box. Connecting wires of lamp cord may be attached to these connections. These wires may be 100 feet long, if desired. No shielding is ordinarily required. A battery of $1\frac{1}{2}$ volts is placed in series in the long microphone wire.

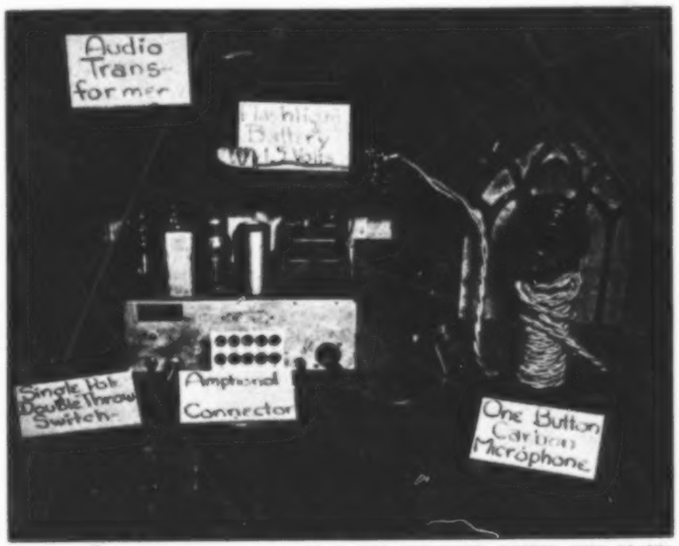

Audio Transformer
Flashlight Battery 1.5 Volts
Single Pole Double Throw Switch
Amphenol Connector
One Button Carbon Microphone

PHOTO BY BERNARD HARTZ, BRISTOL HIGH SCHOOL

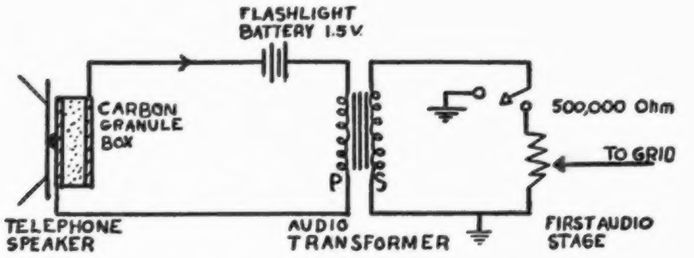
The ends of the two wires should be connected in series to the primary connections of an audio transformer. This is used because the carbon microphone sets up a fluctuating direct current across the secondary. Fasten the audio transformer inside the radio case and the battery on the radio case. Solder all wires to battery and transformer.

Purchase a toggle switch from a radio store, and place it on the back of the radio chassis. Also purchase a screw-in-connection for your microphone wires. Connect the two microphone wires from the secondary of your audio transformer to the screw-in-connection. Make this connection between audio transformer and connector as short as possible to eliminate feedback or else a shielded wire must be used. You are now connected to the chassis.

The toggle switch is necessary in order to allow the radio to be used for ordinary broadcasting as well as for a public address system. Connections inside the set must be made from the switch to the grid of the first stage of audio amplification ahead of the output tube to the speaker. Usually the connection is made to a 500,000 ohm resistance or potentiometer which controls low input to audio amplification stage. A large input lowers the volume of the amplifier. The other connection of the switch goes to the positive of the screw-in-connections. The negative of the screw-in-connector is grounded on the chassis.

The connections inside the chassis may be done by a radio fan. Manufacturers of the radio will send a set diagram and mark the desired places of connections, if requested, or your local radio repair man will make the necessary set connections for a microphone at a nominal cost.

Shielded wire is necessary inside the chassis in order to prevent feedback. Ground the metal shield by soldering to chassis. Older radio sets used the transformer coupling for audio amplification. More



ONE BUTTON CARBON MICROPHONE

modern sets make use of resistance and impedance coupling. Probably resistance coupling in the audio stage is most common in late sets. In all cases the potentiometer or 500,000 ohm resistance is connected through these couplings by shielded wire to the grid of the first audio stage or the output tube.

All you need to produce a powerful public address system is:

An old style stand-up telephone
A radio, any type
An audio transformer—low ratio (1 to 1)
A toggle switch
A screw-on-connector
Lamp cord (any length)
One flashlight battery—1.5 volts

Connections:

Unscrew mouthpiece of telephone speaker
Attach two wires—any desired length
Place flashlight battery in series with wires
Attach wires to primary of audio transformer
Attach audio transformer inside set if possible, or on top of cabinet

Inside set:

Attach connector to back of radio chassis
Attach toggle switch about one inch from screw-on-connector on chassis
Connect two wires from secondary of audio transformer to ground and positive of screw-on-connector
Attach positive of connector to positive of toggle switch by condenser
Attach two wires from toggle switch to potentiometer, using shielded cable

Teacher Demonstrations in Electricity

ROBERT L. BRANDENBURG

Biology Department, Alva High School, Alva, Oklahoma

(MAY 1958)

The types of demonstrations explained here are especially adapted to the classroom teacher who finds himself with too many students and too little space and equipment. In discussing electricity and how it is used with general science students, nothing would be better than for the individual student to have a complete set of electrical equipment and be able to set up his own experiments and demonstrations of the material being studied under the supervision of the instructor. However, when this is impossible due to the shortage of equipment and space, the instructor must resort to the next best method of motivating the students and obtaining the best possible learning situation. This, of course, will be the teacher demonstration so organized that each student will receive an equal amount of practical application. I believe the method of demonstration described here is both practical and beneficial.

Some of the important phases of electricity that should be demonstrated to the students are series and parallel circuits, operation of doorbells and buzzers, action of different types of switches, carbon arc lamp, voltmeters, and ammeters. If the teacher has to assemble these materials each day and then put them away at the end of the class period, much valuable instructional time has been wasted. It will not be wasted if the demonstration material is organized as a complete instructional unit.

The method I am using is to mount all of this demonstration material on a portable panel that may be displayed in an upright position at the front of the classroom in full view of all the students. The first step in developing this method is to decide how much demonstration material is to be used (this can be overdone) and where it is to be mounted on the panel.

An ideal way of laying out this material is to make a scale drawing of the panel with the exact location of each piece of apparatus. One of the primary things to consider at this time is the location of the power supply, whether it be a transformer or dry cell batteries or both. I believe the transformer to be the more convenient. It must be located in such a position as to provide electricity to all of the appliances in the easiest manner. The two output leads of the transformer then should lead to a junction box and be connected to a set of switches so that the current may be directed to whatever appliances the instructor is going to demonstrate. This not only focuses the attention of the students, but also acts as a safety factor. As another safety precaution, the panel should operate on low voltage.

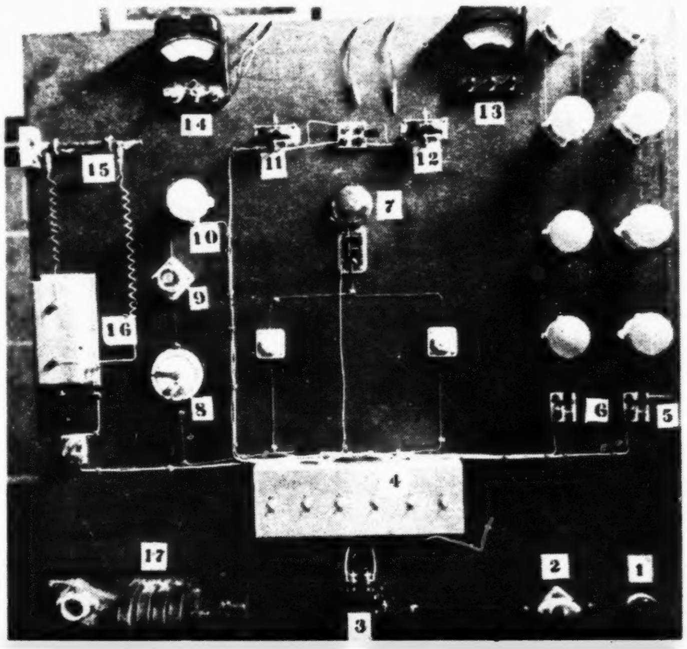
To demonstrate series and parallel circuits, four or five lamps are arranged in the proper order using cleat receptacles as bases. The wire used should be a stiff, bare wire located so that it is plainly visible to the students and they may see the path that the electric current must follow. By unscrewing one or two lamps, it can be demonstrated how the addition or elimination of resistances will affect the rest of the circuit. Instead of unscrewing the lamps, one or two switches may be placed in the circuit to vary the resistance.

To illustrate how a doorbell may be rung from either a switch at the front door or one at the back door, two pushbutton switches and a buzzer are arranged in parallel so that either switch will operate the buzzer independently of the other.

To emphasize the value of safety fuses in the home, a rheostat, a low-voltage fuse, and an ammeter are arranged so that the students can read the strength of current flowing through the circuit. The current can be varied enough by the rheostat to cause the fuse to blow. To make the demonstration more impressive, the wire in the circuit may be hooked up to cause a short circuit that will blow the fuse before the wire becomes overheated. The relationship of short circuits and fires in the home can be pointed out.

To demonstrate electric motors, a St. Louis motor would be preferable; however, a toy motor may be used, especially if it is one that has been assembled by a group of students. The motor should be situated so that the instructor can easily point out the important parts of the motor and the path of the electricity through the motor. Also, all of the wiring leading to the motor will be in full view and the students can easily see the points where the current enters and leaves the motor.

Another easily obtainable and practical piece of demonstration equipment is the telephone generator. This may be mounted so that it can be connected to any of the equipment on the panel. Two binding posts can be installed on the panel so that students may "get the feel" of electricity. I have always found it interesting to the students to have them form a circle holding hands and let the current flow through several of them while someone slowly turns the generator.



1. Master control switch. 2. Red light shows current is to transformer. 3. Six-volt transformer. 4. Control panel: directs current to different appliances. 5. Series circuit. 6. Parallel circuit. 7. Doorbell with two pushbutton switches. 8. Rheostat. 9. Fuse. 10. Resistance to blow fuse. 11. Motor. 12. Motor—switch in between to control operation of second motor. 13. Ammeter. 14. Voltmeter with test leads attached. 15. Carbon arc lamp. 16. Induction coil. 17. Telephone generator. Total cost of panel: $12.57.

As a climax for the unit on electricity and also to stimulate further interest in electricity, the carbon arc lamp may be demonstrated. Even though some textbooks never mention the carbon arc lamp, I have found it to be a very stimulating demonstration. This equipment, too, is mounted on the demonstration panel with the necessary switches and induction coil. In demonstrating this lamp the instructor should point out the space between the carbon tips and what is actually happening. The tremendous amount of heat between the two points may be illustrated by placing different objects such as paper and thin strips of wood between the two points to show how readily they burst into flames.

The demonstrations described here are ones that I have used and have mounted on my demonstration panel. Other instructors may choose different equipment or a different arrangement of the equipment, but the basic principle of the method used remains the same. The panel may be enlarged each year as new and different equipment becomes available. I have found this method so satisfactory that I also have made a demonstration panel for weather equipment to be used specifically when studying weather; however, I have mounted this panel permanently in the classroom. I find that the students are always interested in such weather information as the speed of the wind, relative humidity, barometric pressure, and temperature.

Experiments With an Electrical Network Board

MARTINUS VAN WAYNEN

Counselor and Science Teacher, Berkeley High School, Berkeley, California

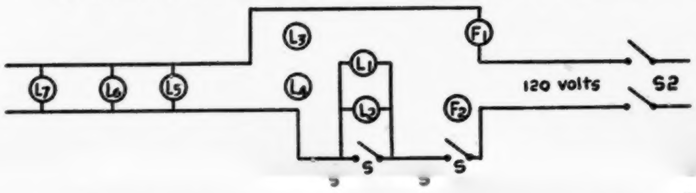
(FEBRUARY 1952)

MY ARTICLE in the November issue of *The Science Teacher* promised a follow-up on an electrical network board and what one could do with it. The 100-watt bulbs shown on the board on page 25 in each case light up with brilliances which corroborate the calculated results. What the teacher can do with a board of this sort follows in outline form.

Let us first number the lamps as shown in the following wiring diagram and then calculate the resistance of one of the 100-watt bulbs. Assuming the line voltage to be 120 volts, the current for a 100-watt lamp can be found by

$$I = \text{watts}/E = 100/120 \text{ volts}$$

$$\text{so that } R = E/I = 120/.833 = 144 \text{ ohms}$$



1. With only L_7 in, the bulb receives the full line voltage of 120 volts and glows with full brilliance.

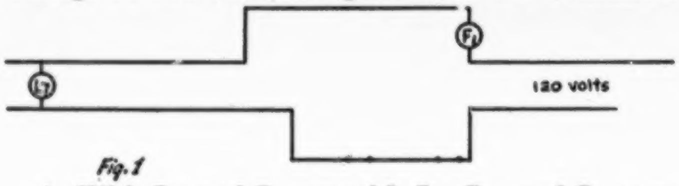


Fig. 1

2. With L_7 and L_6, or with L_7, L_6, and L_5 connected in parallel, each lamp still receives full voltage and glows with full brilliance as in case 1.

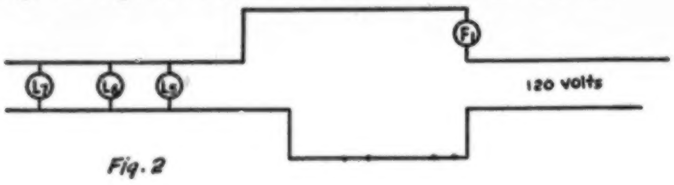


Fig. 2

3. With two in series, each lamp gets 120/2 or 60 volts. The two lamps light up fairly brightly.

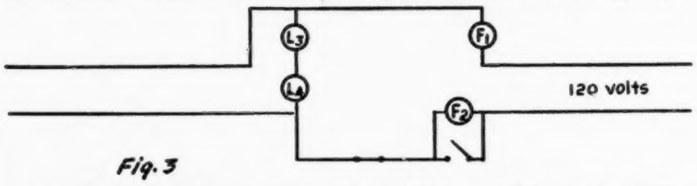


Fig. 3

4. Now replace fuse F_2 with a 100-watt bulb. L_3, L_4, L_2, and L_8 can be connected in series. First, with L_8 out and the switch connected with it closed, the three lamps in series will each account for a drop of 40 volts and will glow dimly. With L_8 in, putting four lamps in series, the voltage drop per lamp becomes 30 volts so that the lamps may barely be seen. By replacing F_1 with another bulb, five lamps in series will be achieved, but in this case the voltage drop is too low to get any perceptible glow from the lamps. In this way pupils should easily learn the principles of a series circuit, at least when the resistances are equal.

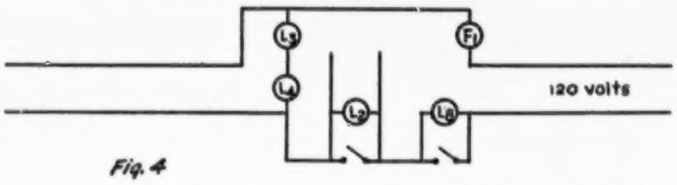
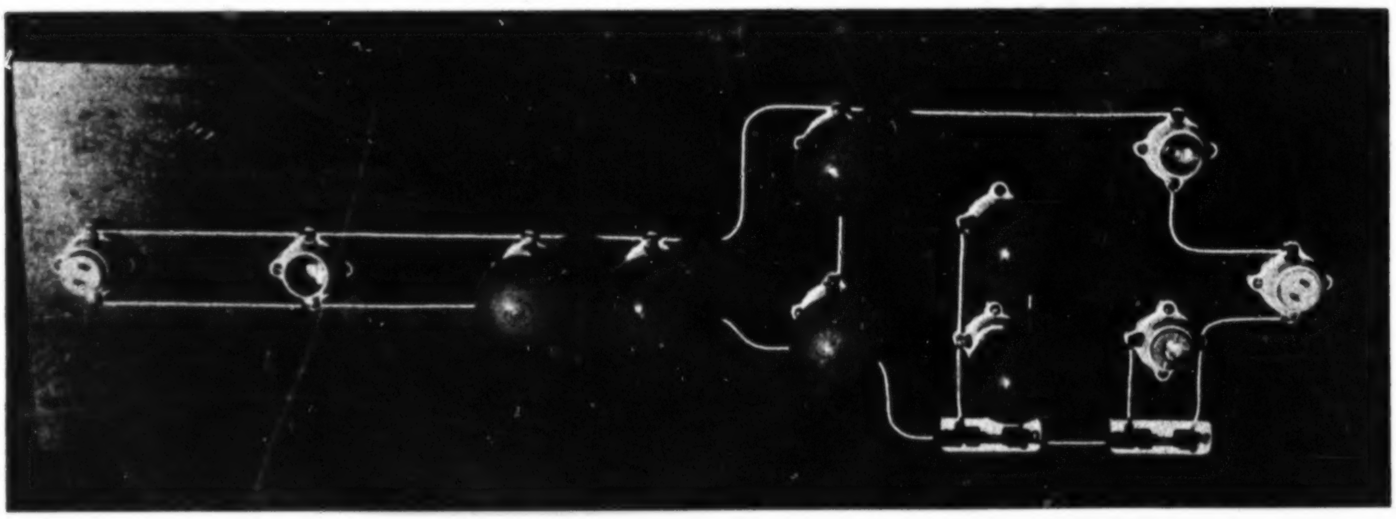


Fig. 4

5. In this case L_2 is connected in series with L_7 and L_6 as shown. The joint resistance of L_7 and L_6 connected in parallel is 144/2 or 72 ohms. This means that the voltage drop in L_2 is twice that in either of the other two lamps. L_2 will be fairly bright while L_7 and L_6 are dimly lighted. At this point in the demonstration take out L_7 so that L_6 and L_2 are in series to see the change in brilliances. Both now getting 60 volts are equally lighted, L_2 becoming less brilliant while L_6 becomes brighter.



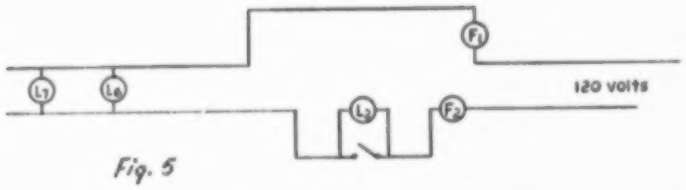


Fig. 5

6. Here L_7 and L_6 are still connected in parallel while L_2 is connected in parallel with L_1 as shown. The four lamps will glow with equal brilliance, although fairly dim, each subject to a 60-volt drop.

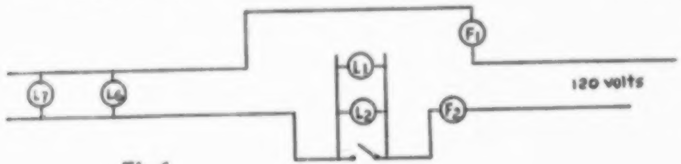


Fig. 6

7. In this network L_7 and L_6 both account for a 120-volt drop while L_3 and L_4 each get 60 volts.

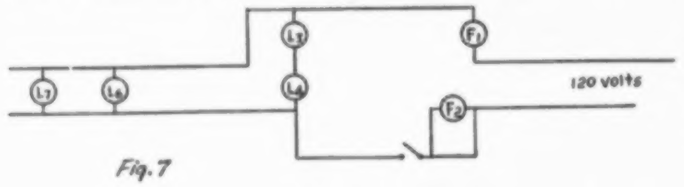


Fig. 7

8. Opening the switch rapidly in this combination will show a slow appearance of glow in L_1 and L_2 and a slow disappearance in L_7 demonstrating the heat-resistance relationship.

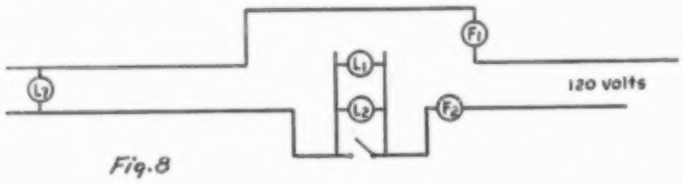


Fig. 8

9. The total resistance is now 144 + 144 + 72 ohms which means that L_4 and L_3 each receive 2/5 × 120 or 48 volts while L_1 and L_2 each get 24 volts. L_3 and L_4 glow dimly, and L_1 and L_2 not at all.

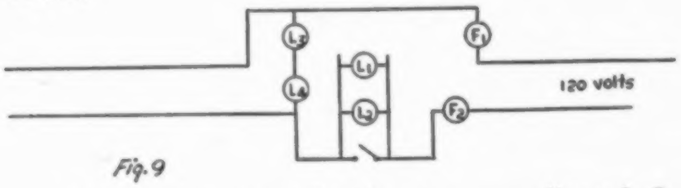


Fig. 9

10. This demonstration is more complicated. L_7 and L_6 connected in parallel are in turn in parallel with L_3 and L_4 in series. All of this is connected in series with the parallel-connected L_1 and L_2. In this case the combined resistance of L_7, L_6, L_3, and L_4 is found as follows:

$$1/R = 1/72 + 1/288 = 5/288$$
$$R = 288/5 \text{ or } 57.6 \text{ ohms}$$

The resistance of L_1 and L_2 combined is 72 ohms. Thus the voltage drop over L_1 and L_2 is 72/129.6 × 120 or 66.6 volts. This leaves 53.4 volts for L_7 and L_6, and only 26.7 volts for each of L_3 and L_4. Close the switch shown and discuss the change in the brightness of the lamps in light of what was seen in case 7.

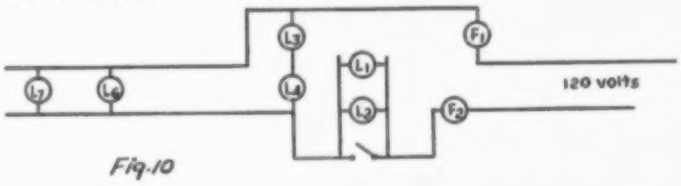


Fig. 10

11. By putting a low amperage fuse in at either fuse plug and replacing L_5 and L_6 by heater elements, one can demonstrate overloading a line and the protection value of fuses. The penny routine can be shown at this point also.

12. Since the wire between L_3 and F_1 is removable, it can be replaced by an iron wire of appropriate size so that it can be made to get red hot showing what an overload actually can do to one's wiring.

13. We will not go into it, but consider the possibilities of the network set up when lamps are placed in all of the sockets on the board.

14. Another interesting circuit can be worked out by connecting the power to the left end, again putting lamps into all sockets including the plug at the far right.

15. Although lamps of different wattage do not lend themselves well to visual demonstration with this board, certain combinations using lamps with widely different wattages may be worked out to advantage.

Other experiments with this board are probably possible. There is no good reason why meters could not be used in conjunction with experiments worked out with the use of the board. This board has been used quite effectively in the experiments given. Its visual value in checking actual results even though approximate should be easily perceived. Why not try it with your class?

Radio-Tube Demonstration Stands

MORTON L. NEWMAN

Science Teacher, William E. Grady Vocational-Technical High School, Brooklyn, New York

(DECEMBER 1951)

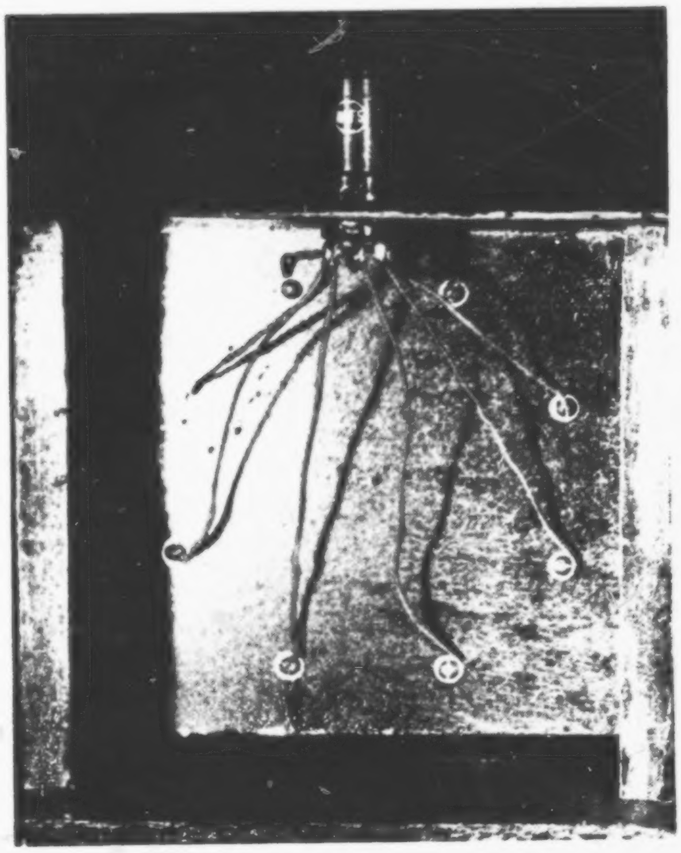
These demonstration stands have been found useful as an aid in teaching radio-tube operations to our "non-academically minded" boys.

Materials were scrap wood and masonite. None of the dimensions are critical, except for the hole in the top for the tube socket.

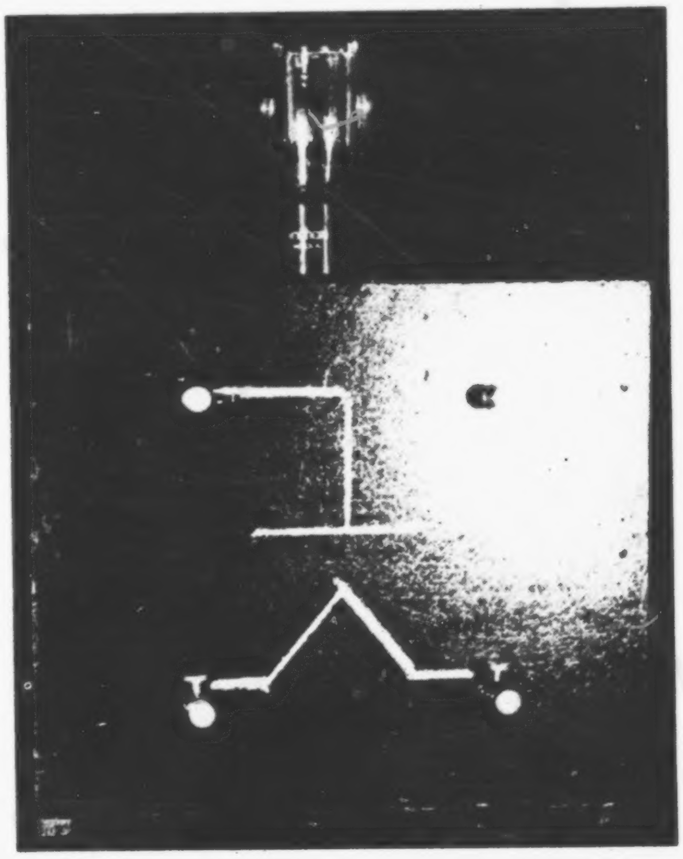
After the wires have been soldered to the socket, mount it with the slot in octal sockets or the larger holes in four-contact sockets toward the rear of the stand. Then the wires can be attached under the screws of the connectors in their proper order, so that as seen by the class the number 1 prong is at the lower left.

At least the front should be painted black. Stove enamel seems satisfactory.

This arrangement has several advantages: (1) various tubes may be used with the same socket; (2) connections can be made quickly with alligator clips or bare wire ends; (3) a schematic diagram of the tube may be chalked on the face of the stand while tube operation is being studied—a wet cloth erases the chalk; (4) the stand is large enough to be seen by the whole class.



Rear view of octal socket stand.



Front view of four-contact stand.

An Electro-Mechanical Television Analogy

HARRY MILGROM

Assistant Director of Science, New York City Schools, New York, New York

(MARCH 1954)

Do you have difficulty in making clear and understandable the answers to such "television questions" as these?

1. How is the iconoscope image scanned?
2. What is a scanning line?
3. What is interlaced feedback?
4. What is sweepback?
5. How is the image reproduced in the kinescope?
6. What is meant by synchronization?
7. What causes image distortion?

You can make a simple model to answer these questions. Construct the device this way.

1. Mount two picture frames (approximately 16 x 14 in.), side by side, on a baseboard to represent the transmitter and receiver image screens.

2. Insert in the left-hand frame (#1 in the diagram) a metal plate of galvanized iron on which is cemented a white cardboard stencil of the picture to be transmitted. This screen represents the iconoscope screen.

3. Place in the right-hand frame (#2) a second metal plate over which is tightly stretched a piece of white sheeting. This screen represents the kinescope screen.

4. Between the two screens and about half an inch in front of them, mount two quarter-inch rods of brass or dowling vertically (#3 in the diagram).

5. Make part #4 by soldering together lengths of brass tubing, such as curtain rod tubing with an inside diameter of 9/32 in., to form a rectangle. Adjust the spacing of #4 so that it does not move too freely up and down the vertical rods (#3).

6. Place a 3-foot length of quarter-inch dowel through the lower brass tube so that is free to move horizontally (#5). Drill the dowel at points marked "X" to accomodate the electrodes.

7. Attach two copper electrodes made of #12 wire and bent into loops for contact with corresponding portions of the two screens (#6A and #6B).

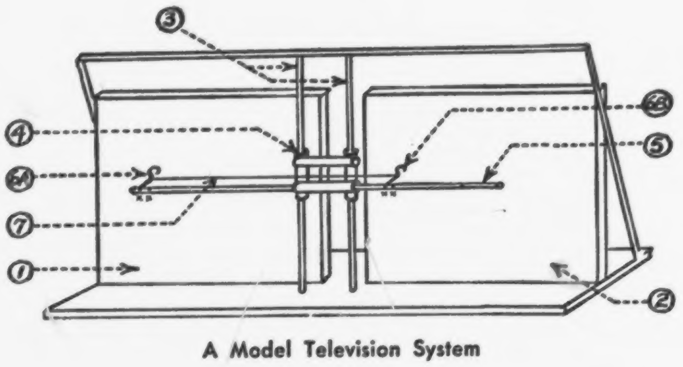
8. Connect the two electrodes with an insulated copper wire running between them outside the tube (#7).

To operate the model in order to answer the questions, proceed as follows.

1. Connect the back of screen #1 to the positive terminal and the back of screen #2 to the negative side of a six-volt storage battery.

2. Dampen the white sheeting over screen #2 with a concentrated solution of potassium iodide.

3. Lift the rectangle (#4) to the highest point, move the dowel (#5) to the extreme left, and twist it so that the electrodes are pressed firmly against the screens.



A Model Television System

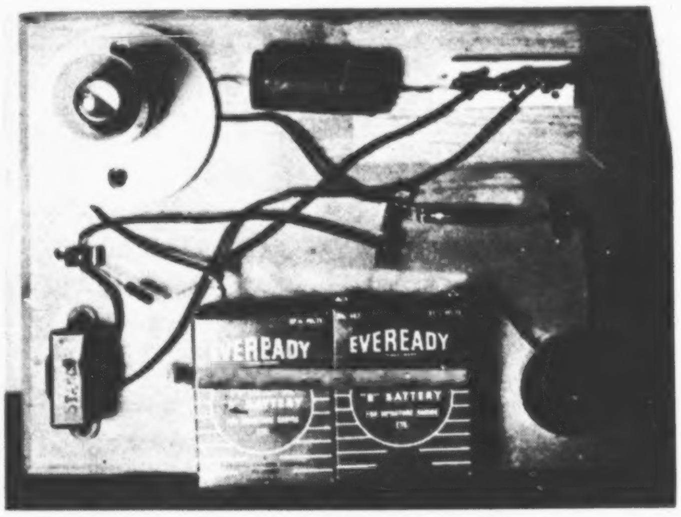
Demonstrating Chokes and Condensers

JAMES E. CREIGHTON

Science Teacher, Nathan Hale Junior High School, Norwalk, Connecticut

(MARCH 1952)

The difficult problem of demonstrating and explaining the workings of electrical condensers and choke coils can be solved simply and inexpensively. Most science teachers are aware of the difficulty high school students have in grasping the illusive concepts of self inductance of choke coils and the charging and discharging of electrical condensers. The following paragraphs show how the science teacher can make three simple "breadboard" circuits which will be of immense value as visual aids in teaching these principles. By using a neon lamp as sort of an indicator of what is happening in such circuits, the student can readily "see" the elasticity of condensers and the momentum effect of self induction upon current.



Figures 1, 2, and 3 show schematically a neon lamp being used with a choke and condenser to make simple D. C. demonstration apparatus. Figure 1 is a simple relaxation oscillator circuit similar to that used in the sweep circuits of cathode-ray oscilloscopes and certain time-delay tubes. The high resistance in series with the neon lamp keeps the voltage across the lamp below its normal starting voltage of 85 volts. However, as the current leaks through this resistance, it gradually charges the condenser to a voltage high enough (85 volts) to light the lamp. The condenser then immediately discharges through the lamp causing it to flash on momentarily. As soon as the voltage on the condenser drops below the sustaining voltage of the lamp (about 65 volts) due to the discharge of the condenser, the lamp goes out. The condenser immediately begins to charge up again and repeats its discharge through the lamp, thus causing a continuous flashing on and off of the lamp at a frequency dependent upon the size of the resistance and capacitance of the circuit.

FIG. I

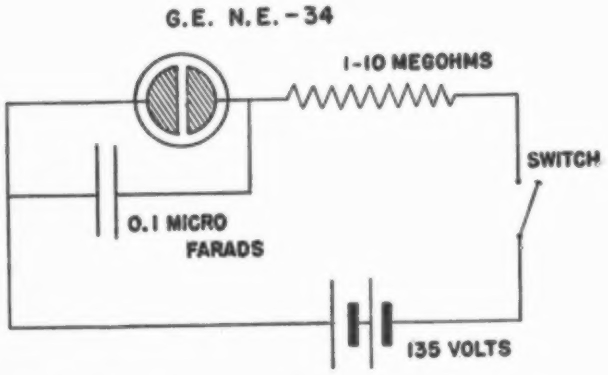
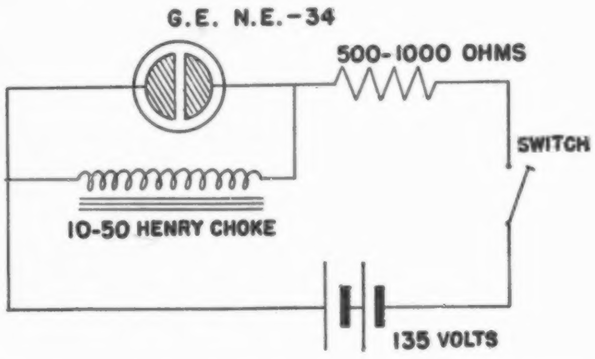


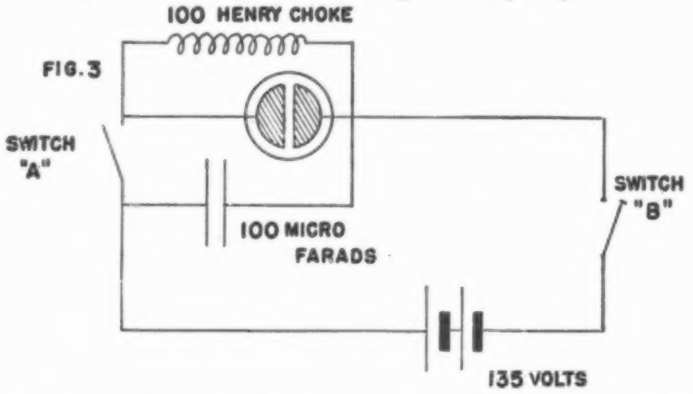
Figure 2 is the same circuit as in figure 1 with a choke substituted for the condenser and a much smaller resistance in series. When a steady current flows, the lamp is dark, because the low-resistance choke coil bypasses most of the current. But, whenever this current is started or stopped, the lamp glows. Current cannot begin to flow or stop suddenly in a choke coil because of its large self inductance. Therefore, at the moment the switch is closed most of the current flows through the lamp. Then, again, when the switch is opened, the current tends

FIG. 2



to continue in the coil and necessarily finds its way through the lamp again. Note: opposite sides of the lamp glow.

Figure 3 makes use of both condenser and choke thus producing an oscillation which gradually damps out. The condenser after being charged is allowed to discharge by means of switch "A" through the lamp and choke. But, owing to the coil's self induction, the current cannot build up to its full amplitude at once; it gradually builds up (like a mass getting into motion) and reaches its greatest value just as the condenser plates are discharged. Now the current cannot stop at once; it continues, and the condenser is charged up in the opposite direction. Then the current reverses, again gradually builds up in the coil, and recharges the condenser to almost its original voltage. Thus the current continues to flow back and forth, but is gradually damped out by the resistance. At each charging of the condenser the neon lamp glows. It flickers on and off until the voltage falls too low to excite the glow. This is obviously an exact analogy to a weight oscillating on a spring.



These three circuits make excellent visual-aids for general science and high school physics because of their inexpensiveness, simplicity of construction, and their versatility and spectacular nature. This apparatus would not only help greatly in teaching the difficult concepts of the charging and discharging of condensers and self-inductance, but it can explain circuits and neon lamps and stimulate much interest in electricity. These circuits are rather advanced for the general science class, but they are spectacular and this factor alone merits their use.

LIST OF MATERIALS:

1. Bell wire.
2. Two 67½ v. "B" batteries.
3. Neon lamp. General Electric (NE. 34) excitation volts, 80; sustaining volts, 60.
4. Several resistances (1-10 megohms; 2 watts).
5. Several condensers (.5, 1, 1.5 mocrofarads).
6. One condenser (about 100 mfds.).
   Caution: do not use polarized condensers in the circuit of figure 3 because the condenser charges in both directions.
7. One 100-henry choke.
8. One 10-to-50-henry filter choke. (The above 100-henry choke can be used in place of the 10-to-50-henry choke in figure 2.)
9. Several switches.
10. One 500-1000-ohm resistance, 2 watts.

THINGS TO DO:

1. Try different sized resistances in circuit 1.
2. Try different sized condensers in circuit in figure 1.
3. Remove high resistance in circuit in figure 1 and observe.
4. Remove high resistance and complete circuit by having class join hands.
5. Reverse leads of battery and observe lamp in figure 1.
6. Remove choke from circuit of figure 2 and observe.
7. Observe which side of lamp flashes on when the circuit is turned on, when it is turned off in figure 2.
8. Try placing some resistance in series with the choke in figure 3.
9. Observe which side of the lamp flashes in circuit in figure 3. Is this different from what happens in circuit 1? Why?

More PHIZ in the Physical Sciences

J. EDGAR MORRIS

Chemistry Teacher, The Lovett School, Atlanta, Georgia

(NOVEMBER 1952)

Sometimes it is well to begin by defining words. Let us have no one get the idea that by *phiz* we mean letting the students' interest in the physical sciences, chemistry and physics, fizzle out. This is what we would like to prevent. I feel that one way to stimulate interest in these subjects is to utilize experiments and demonstrations that will arouse the students' curiosity. Most of us would agree that another way is to relate these subject areas of science to the students' everyday life experiences.

Here is a very simple experiment using readily available materials, that may be used for either of the following purposes: (a) to introduce the students to a study of CO_2 gas; (b) to demonstrate the principle of the foam-type fire extinguisher. We have here baking soda ($NaHCO_3$), Dreft washing powder, hydrochloric acid (vinegar could be used as a substitute), and an indicator, methyl orange. Note that even if this experiment is used early in a chemistry course the majority of the materials are already familiar to the students. I think it is a good idea to have some familiar materials and to introduce the students to at least one new material with each experiment or demonstration. We also have a large battery jar. If this is not readily available a one-gallon commercial size mayonnaise jar or other large glass container may be used.

I now fill the glass jar about one-fourth full of water, and to this I will add about four tablespoonfuls of baking soda and about twice this amount of Dreft. Note that a large container is used and enough materials so that the students in the back of the room do not have any difficulty in seeing exactly what is happening. To get colored bubbles and also show how an indicator works I will now add about 10 ml. of methyl orange solution and stir it until it is evenly distributed throughout the solution. Note the distinct orange color produced, showing that the solution is basic.

Before adding the acid to this mixture I will now ignite a mixture of used motor oil and gasoline in this pan. When it is burning the flame is readily visible throughout the room.

Now I shall add about 100 ml. of hydrochloric acid (1 to 4 concentration) and stir this into the mixture in the battery jar. Note that the color changes to pink, indicating that the solution is now acidic. Note also the copious volume of foam, which is fairly stiff and resembles a cherry soda (students sometimes ask if this is good to eat). Now to show how a foam-type fire extinguisher smothers a flame, I shall dip this foam out of the battery jar and place it on the burning oil. Notice how it spreads and puts the fire out. If a larger volume of foam had been produced, I could have tilted the jar and let the foam spill over into the burning oil. If a more stable type of foam is desired you may add some aluminum sulfate to the baking soda solution before adding the acid. Some commercial foam type fire extinguishers do use the aluminum sulfate.

How do you demonstrate that evaporation absorbs heat? Here is one simple way that never fails to attract attention. It clearly and vividly puts this idea across. I call this "cold fire." In an ordinary evaporating dish I place about 10 ml. of carbon tetrachloride (CCl_4) and about 6 ml. of carbon disulphide (CS_2). Both of these substances are volatile. The CS_2 burns readily, while the CCl_4 will not burn—in fact it is used as a fire extinguishing agent. I will now ignite this mixture. Note that it burns with a pale flame. While it is burning, I will dip my fingers down into the mixture and slowly lift them up so that you can see the fire burning on my fingers. No, it is not hot. In fact it even feels cool. The explanation is simple. The heat from the burning CS_2 is utilized in evaporating the CCl_4; therefore, if your proportions are right you actually have cold fire. Before you try this with your class, you should try it out first yourself. If the mixture does not burn, add a little more CS_2. If it feels warm when burning on your fingers, add a little more CCl_4.

Now I would like to say a few words about relating classroom activities to the students' everyday life experiences. Most general science classes and physics classes take up a unit of work on electricity sometime during the course. Too often the introduction to this topic is not presented in a manner that shows that it is in any way related to everyday life. This need not be the case. I am suggesting that as an introduction, a teacher might well have in his classroom as many of the following home appliances as he can obtain (usually an appliance dealer in the community will give or loan used items of this nature to the school): vacuum cleaner, refrigerator, mixer, electric coffee maker, hot plate, waffle iron, flat iron, etc. All of the students are already familiar with the most of these items. Introduce the unit by asking them how these work. Before you know it, they will be digging into Ohm's Law and all of the other laws and terms used in the unit. The difference will be that this time they will be doing it because they want to and not because it is an assignment.

Statistics show that the women of our country are constantly controlling an increasing proportion of our wealth. I suggest that they are also operating an increasing number of electrical and mechanical appliances in the home. Therefore if our physics courses are adapted to center largely around these appliances, I firmly believe that more girls will elect to take physics. Both boys and girls will get more out of the course if they are stimulated to learn about these things because of their practical uses.

From this presentation I hope you have observed that my theory is that we can put more "phiz" into the physical sciences by: (1) using experiments and demonstrations that will not only illustrate a point, but that will stimulate a student's curiosity, and (2) relating the subject matter to the students' everyday life experiences.

The Slow Learner Wants to See It Work

MORTON L. NEWMAN

Science Teacher, William E. Grady Vocational-Technical High School, Brooklyn, New York

(MARCH 1952)

In addition to their difficulty with words and numbers, slow learners may find it virtually impossible to form clear concepts of abstractions, including electromagnetism. They may, however, have the ability to appreciate, on an elementary level, how a device works.

To reach his pupils, the teacher of the slow learner must have recourse to every form of visual aid—charts, slides, movies, the device itself, etc. Yet many of these aids seem also to be essentially verbal or pictorial *descriptions* and not demonstrations of the actual operation. Even the use of the device itself may force the teacher to depend too much on words, for often the device is far too small or its motions much too rapid to be seen clearly by the class.

Below are descriptions of specially built supplements to the usual visual aids, designed to reach the slow-learner. The apparatus in each case has been made as large and as slow-moving as possible, and wherever feasible the flow of current is indicated by the lighting of a bulb in the circuit.

1. Telegraph (Fig. 1). This is merely a greatly enlarged model with a bulb in series with the coil.

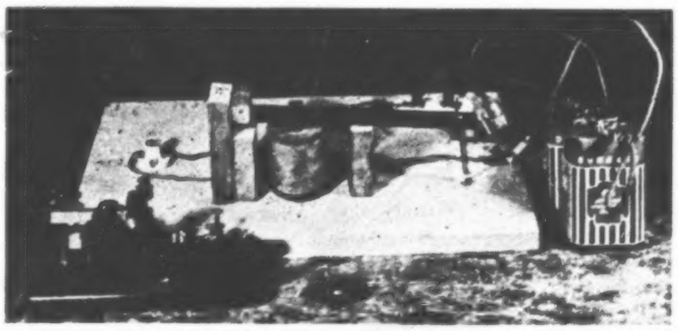


Figure 1. Enlarged model of the telegraph

2. Relay. This is a modification of the above model of the telegraph. A strip of copper is placed on the lower armature stop to serve as a contact point when the armature moves down. Two bulbs, a dim light in the coil circuit, and a brighter light in the relay circuit, serve to demonstrate the uses of a relay.

3. Buzzer or Bell (Fig. 2). Again, this is merely a very much enlarged model. The spring is a brass strip riveted to a small iron armature. The bulb, in series with the coil, flickers on and off as the armature moves slowly. The operation may be performed manually to slow it down to the word-production rate of the teacher or a pupil.

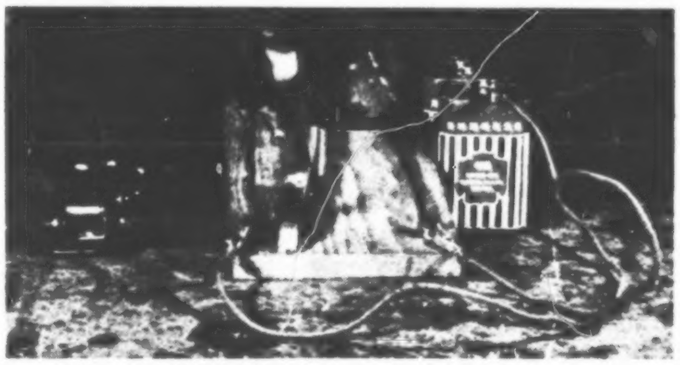


Figure 2. Enlarged and slow-moving model of a bell.

4. Induction Coil (Fig. 3). The principle that current flows in the secondary only on the make or break of the primary circuit is usually difficult to establish without much verbalizing. However, a few minor adaptations of the apparatus may simplify matters. Adjust the points so that they stay closed whenever the primary current is on. Also, connect a small bulb in the primary circuit. To the secondary terminals connect a neon glow lamp. When the switch in the primary is closed, the neon lamp in the secondary glows only momentarily,

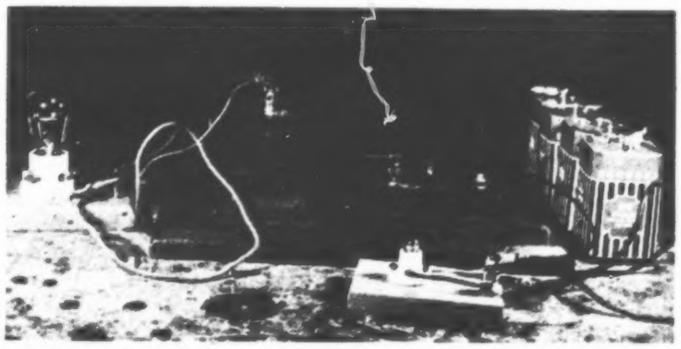


Figure 3. Induction coil connected to a neon glow lamp.

while the small bulb stays lighted. When the switch is opened, the small bulb goes out, but the neon lamp again glows momentarily.

It is even possible to point out the changing direction of the current in the secondary, since alternate plates in the glow lamp flash on and off with the make or break of the primary circuit.

5. MOTOR (Fig. 4). This model was constructed with the purpose of indicating the changing polarity of the armature by means of illuminated letters "N" and "S."

Only one of the brushes (made of strips of brass) is actually connected to the batteries; the other is "dead." The commutator is built of two copper strips mounted on a piece of round wood about one inch wide and two inches in diameter. Each segment of the commutator is wired separately to one of the two parts of the armature coil. The armature coil looks like one continuous winding, but it is actually in two independent parts.

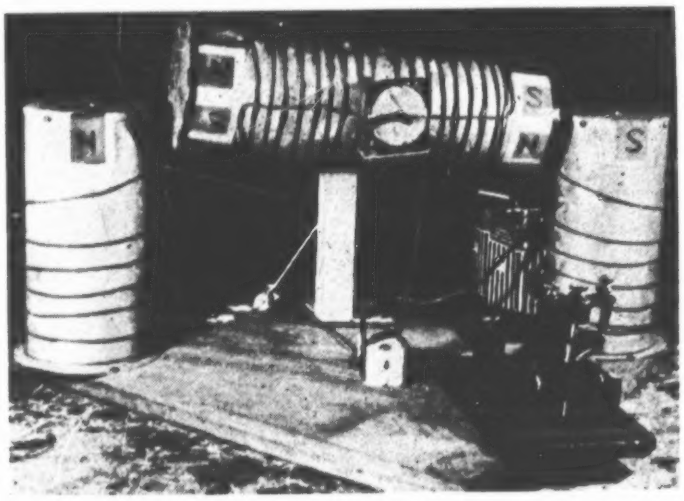


Figure 4. Model of a motor.

Inside the hollow armature (metal or cardboard cylinder) there are two sets of two light bulbs. Each set is wired in parallel through one part of the armature winding to one of the segments of the commutator (see figures 5 and 6).

The metal armature and the one-quarter-inch shaft serve as the common ground. Windows are cut out of the armature so that the bulbs illuminate the appropriate "N" or "S" labels.

As the armature is made to revolve, the "N" and "S" on opposite sides glow. At the proper moment, when the armature poles are closest to the field coils, the live brush makes contact with the other segment of the commutator. The other set of two lights goes on, indicating the change in polarity.

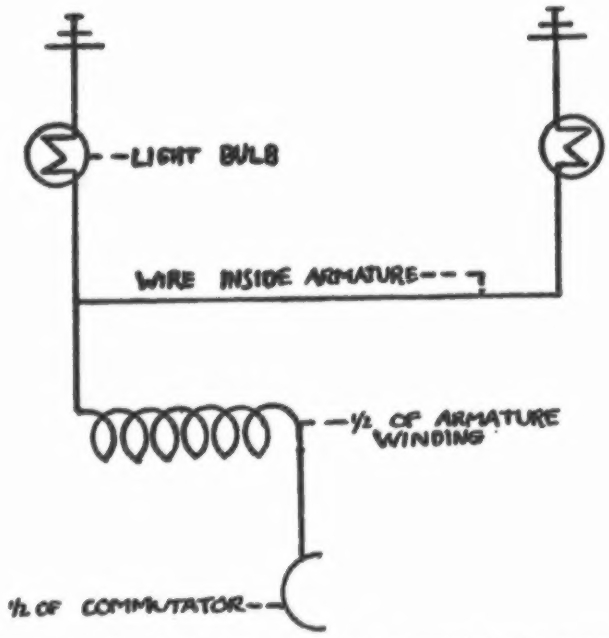


Figure 5. One half of the wiring for the model of a motor.

The actual rotation is done manually. (In one model the armature was driven by an induction motor geared down to six rpm.)

The field magnets are similarly made of hollow metal cylinders, each with a single light behind a window.

The light-bulb sockets were mounted on the circular caps on the ends of the armature and the field magnets.

6. TELEPHONE. A. (Fig. 7). A carbon-disc rheostat may be used to demonstrate the operation of the carbon box in the transmitter. As the carbon discs are tightened, the light in series glows

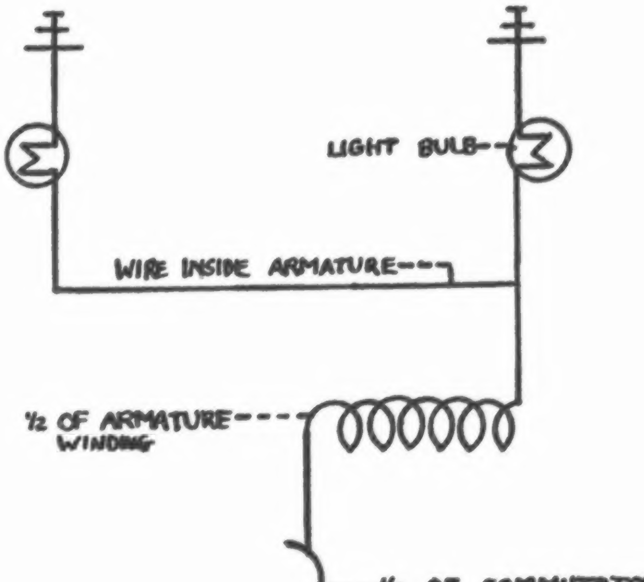


Figure 6. Second half of the wiring for the model of a motor.

brightly; when the carbon discs are loosened, the light dims. To make the analogy with the telephone, a light is connected with a telephone transmitter and batteries. Pushing the diaphragm manually causes the brightness of the light to vary.

B. (Fig. 8). An enlarged model of a receiver may be used to demonstrate that as the transmitter diaphragm vibrates, the receiver diaphragm vibrates correspondingly.

The receiver diaphragm is a circular piece of sheet iron six inches in diameter. The electromagnet is the common horseshoe lifting magnet. A wooden base and supports hold the magnet and the diaphragm. As the transmitter diaphragm is moved manually, the light bulb glows, and the receiver diaphragm is attracted toward the electromagnet.

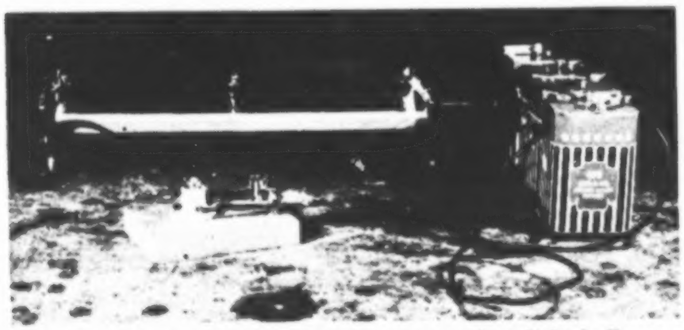


Figure 7. Carbon-disc rheostat connected to light bulb.

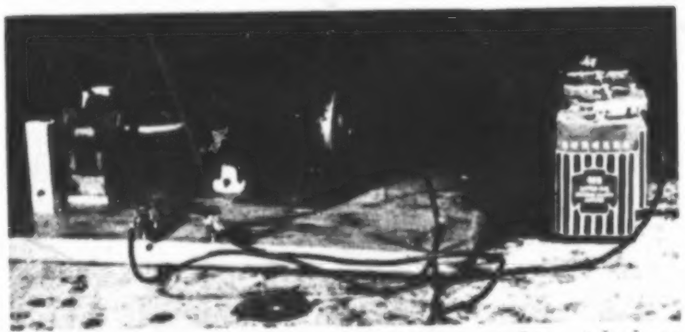


Figure 8. Model of a telephone receiver connected to a telephone transmitter.

These visual aids were not intended to preclude the use of any of the other teaching aids customarily found in the science classroom. They were devised particularly to assist in the teaching of the slow learner. However, the idea of using large and slow-moving models might also be of help to the teacher of normal or bright groups.

A Problem-Solving Demonstration

ARTHUR W. SMITH, JR.
Plainfield High School, Plainfield, New Jersey

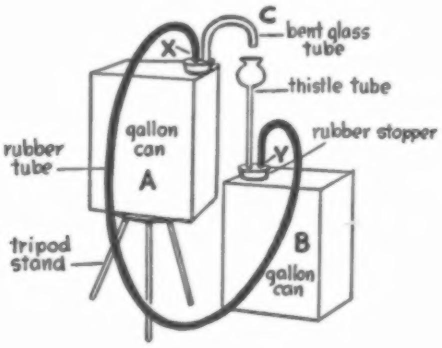
(NOVEMBER 1955)

I should like to share an idea which I have found works very successfully as an "opener" for my ninth-grade general science classes. It is an exercise to get across the concept of *the use of the scientific method in solving problems.*

There were three major objectives about which I was concerned:

1. To try to create as much student interest at the start of the general science course as possible.
2. To demonstrate first hand how the scientific method operates.
3. To "feel out" the students (to see who knows what, to see how as individuals and as a group they operate to solve problems.

As soon as administrative details were finished on the first day of school, I pulled up from behind the demonstration table the following set-up and called upon everyone to watch carefully what happens.



In the above apparatus, care was taken to have the rubber hose at points "x" and "y" completely covering the glass tubes. (Details as to what is inside the cans is presented in a later paragraph of this account.)

I filled a large beaker with water from the faucet and began to pour it into the thistle tube.

When the beaker was about half empty, a red colored liquid flowed up through the bent glass tube (c) and poured into the thistle tube. I then stopped pouring water from the beaker. The flow of red liquid from can A to can B continued uninterrupted for about fifteen minutes.

Students were allowed to come up and carefully look at the apparatus while the red liquid was flowing from can B, but *no one was allowed to touch.* After everyone had a good look at what happened an assignment was made for the students to *write out their observations* and *as a result of these observations to try to figure out the "why" of this demonstration.*

The next day the students were called upon to give their observations as to what happened. At this point the discussion was directed along the lines of accuracy of observation and accuracy in reporting correct sequence of observations. After the class agreed upon the observations they were called upon to present their "ideas" in explanation of what happened. (The term "hypothesis" was taken up later.) Each student was encouraged to contribute, even the students who were "sure their solution just couldn't be right." The ideas were discussed and challenged by different members of the class. As a result many were rejected and the class seemed to agree upon those which could be possible. The two ideas which received the greatest support were as follows:

1. Some sort of chemical action took place in cans A or B to change the color of the water and to force it out of can A.
2. Can A contained a red liquid to start. When water was poured into can B, air was forced out of B which in turn forced the colored liquid out of can A.

Both of these ideas seemed feasible to different members of the class. The question was then asked how they could find out for sure. Someone suggested that the demonstration be repeated. It was. They watched carefully, but soon realized that they could go no farther until the contents of the cans were examined. I then allowed some students to come up and remove the stoppers and examine the contents of the cans.

Can A was found to be filled nearly to the top with a red liquid (Tintex dye in water). The bent glass tube (c) extended to the bottom of the can. Can B was found to be "empty." (After discussion it was brought out that it was full of air—but no liquid.)

With this new information the discussion proceeded more rapidly. Idea #1 about the chemical reaction was discarded. Idea #2 about the water which was poured into can A forcing air out of the can through the hose and into can B to force the red liquid out was developed. The question now was: "While this idea seems good, how can we be sure?" "How can we test this idea to see if this is what really happens?"

Ideas for experiments were not long in coming. Each idea was subjected to experimentation. The following two simple tests proved very convincing:

1. To prove that air will force the liquid from can A was shown when a student disconnected the hose at point "y" and blew through it into can A.
2. To prove that when water is poured into can B air is forced out was shown when a student filled a pan with water to see if bubbles were formed when water displaced the air in the can.

After the solution of this problem was worked out, attention was directed toward the steps followed in arriving at the solution of the problem. It was pointed out that, whether the students knew it or not, they were following the steps of the scientific method in solving their problem. What were these steps?

1. Observations
2. Developing hypotheses as a result of these observations
3. Discussion and evaluation of these different hypotheses (sharing ideas)
4. Obtaining more accurate observations (demonstrated by closer examination of the apparatus)
5. Formulation of new hypothesis as a result of new information gained
6. Experimentation to test hypothesis

Thus, with this exercise in which the students actually work out a problem by using the scientific method, it was possible to effectively present concepts of hypothesis, theory, principle, law, etc. And what was probably even more important, *the class got off to a good start in which there was very high pupil interest.*

Paper Chromatography

FRANCES WHITE WALKER
College Park, Maryland

(OCTOBER 1951)

PAPER chromatography is a method of analysis, which has become popular in the last few years, for the separation and identification of some exceedingly complex materials. The word chromatography is derived from the Greek "chroma," meaning color, and "graph," meaning write. Paper chromatography implies that the compounds identify themselves on the paper by colored spots or bands. The separation of one substance from another depends on the rate of diffusion of the liquid in the paper or on the degree of adsorption of the substance by the paper. It is well known, for example, that water spreads over paper faster than alcohol and that ions such as potassium and phosphate are adsorbed more strongly than those of sodium or chloride. After the materials have been separated on the paper, they may be identified directly if they are colored; or if they are colorless, characteristic reagents may be added to produce a colored compound. For example, the constituents of a colored ink may be observed directly, but an ion such as aluminum is treated with the reagent aluminon to produce a red compound.

The purpose of this article is not to give an extensive treatise on paper chromatography but simply to describe the procedure which was used in preparing an exhibit for a high school science fair. The importance of this method of analysis is indicated by the fact that in the period from 1948 to 1949 over 200 papers appeared in scientific journals on this subject. A few references are given at the end of this article for the benefit of those who wish further information.

The following is a list of materials that are needed to carry on the procedure described:

Black ink—Sheaffer's Skrip Washable Black
Brown ink—Sanford's Penit
Yellow dye—mentanil yellow (or any water soluble yellow dye) 0.1% water solution
Green dye—malachite green (or any water soluble green dye) 0.1% water solution
Mercurochrome—2%—5 ml. of water solution
Nickel chloride—5%—10 ml. of water solution
Ferric nitrate—5%—10 ml. of water solution
Aluminum nitrate—5%—10 ml. of water solution
Lead nitrate—5%—10 ml. of water solution
Bismuth chloride—5%—10 ml. of solution in 5 ml. of conc. hydrochloric acid plus 5 ml. of water
Antimony trichloride—5%—10 ml. of solution in 5 ml. conc. hydrochloric acid plus 5 ml. of water
Cupric sulfate—5%—10 ml. of water solution
Dimethylglyoxime—0.1 g. in 10 ml. 95% ethyl alcohol
Potassium ferrocyanide—10%—10 ml. of water solution
Aluminon 0.1%—10 ml. of water solution
Potassium iodide—10%—10 ml. of water solution
Hydrogen sulfide, aitchtuess—1 oz.
Hydrochloric acid—about 10%—50 ml.
Acetic acid—about 10%—50 ml.
Filter paper qualitative quality as Whatman Number 1—200 sheets—5 cm.
Filter paper—100 sheets—11 cm.
Filter paper—30 strips of 10 by 1 in.
Filter paper—15 strips of 6 by 3 in.
Medicine droppers—6

Experimental Procedure

Black ink demonstrates vividly the various methods that can be used to separate materials. In the descriptions below a drop refers to the drop as obtained from a medicine dropper.

Solvent moves up. (Figure 1) A drop of ink is placed three-quarters of an inch from the bottom of a ten-by-one-inch strip of filter paper (Figure 1). The strip is suspended in a milk bottle so that the lower one-half inch below the ink spot touches the water in the bottom of the bottle. A cork is placed in the bottle to hold the paper and to prevent evaporation. After about 15 minutes the various constituents of the ink will appear on the paper separated in distinct layers. The paper is then removed from the bottle and suspended with a clothes-

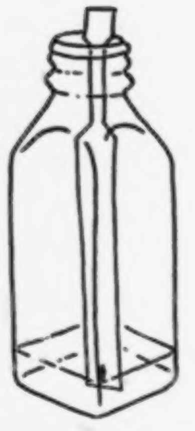


Fig. 1
Solvent Moves Up

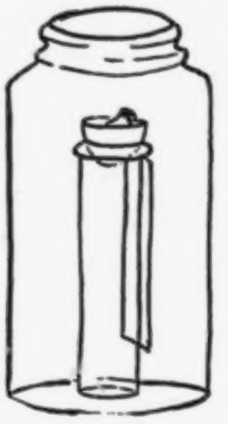


Fig. 2
Solvent Moves Down

pin to dry.

Solvent moves down. (Figure 2) Place a small olive bottle in a wide-topped quart jar. On top of the bottle put a crucible half filled with water. Put a drop of ink an inch from the top of a six-by-one-inch strip of filter paper and put the top end of the paper in the water in the crucible. A stone on the paper will hold it in place, and a cover on the jar will stop evaporation. After the constituents have separated down the paper, remove the strip and let it dry.

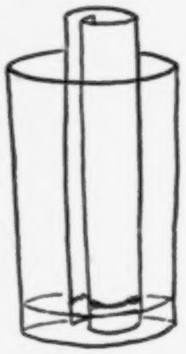


Fig. 3
Cylindrical Paper

Cylindrical paper. (Figure 3) Roll a piece of filter paper six inches long and three inches wide into a cylinder and fasten by cutting tabs in the paper. Place a line of ink one-quarter inch wide completely around the cylinder three-quarters of an inch from the base. Set the paper cylinder in one-half inch of water until the colors separate.

Center cotton wick. (Figure 4) Place a small wad of raw cotton through a hole in the center of a piece of 11-centimeter filter paper. Put ink on the paper around the wick. The tip of the cotton is then put in water by placing the paper on a tumbler nearly full of water. When the rings of color separate on the disc, remove the wick from the water.

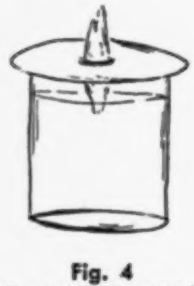


Fig. 4
Center Cotton Wick

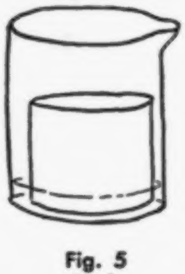


Fig. 5
Pack

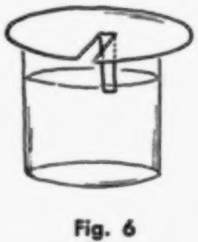


Fig. 6
Disc

Pack. (Figure 5) Using 200 sheets of 5-centimeter filter paper, place five drops of ink on the 20th piece of paper from the bottom. Put the pack in water up to the tenth sheet and place a pound weight on top of the pack. In about 12 hours the ink will reach the top and the pack may be separated into sections of different colored constituents of the ink.

Disc. (Figure 6) Using 11-centimeter paper, cut a strip one-quarter inch wide nearly to the center of the disc. Place a drop of ink on the middle of the strip. Place the disc on a glass and let the tab touch the water, as shown in the diagram. Remove when constituents are separated.

Creased paper. (Figure 7) A rectangular piece of six-by-one-inch filter paper is creased lengthwise, and a few drops of ink are placed on the crease three-quarters of an inch from one end. The paper is placed in a test tube that has one-half inch of water in the bottom. Remove when the constituents are separated.

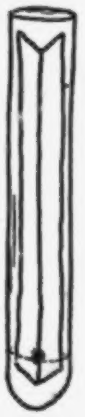
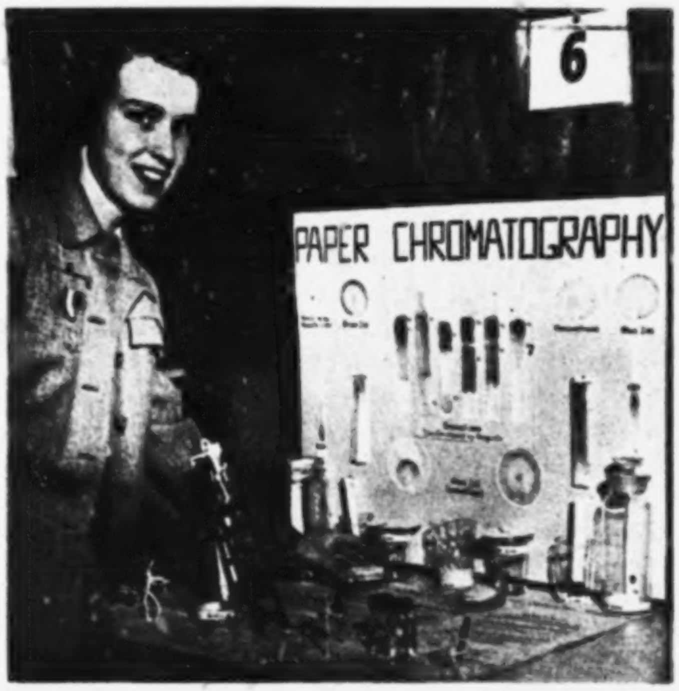


Fig. 7
Creased Paper

Any of the preceding methods may be used in the separation of ions and compounds, but some are found to be better than others. For the separation of various inks and mercurochrome, the disc is good. In using the yellow and green dye, a drop of each is placed together on the wick of the disc, as explained with the ink. These are some examples to try; other dyes and inks make interesting experiments.

The ten-inch strips with the solvent moving up are good for separating compounds and ions. The same procedure is used as with the ink. A drop of solution containing a mixture of ions is placed near the bottom of the paper, and the end of the paper is suspended in a solvent. When the solvent has been absorbed most of the way up the strip, the paper is removed and reagents are then applied to the paper with a medicine dropper. To show separations of the metallic ions, the following combinations are good: nickel and iron; aluminum and lead; bismuth and antimony; iron and aluminum; copper and aluminum; iron and lead; nickel and lead.

Reagents used for development are: aluminon for aluminum; potassium iodide for lead; potas-



Science Service Photo

Frances White at the 1950 National Science Fair where her work on paper chromatography merited a first award.

sium ferrocyanide for iron and copper; dimethylglyoxime for nickel; hydrogen sulfide gas for bismuth and antimony. The proper selection of a solvent is important. One must be chosen which will not react with the ions to be separated, and cause precipitation. In the combinations above ten per cent acetic acid should be used when the material contains lead, and ten per cent hydrochloric acid with the bismuth and antimony mixture. Water may be used in all of the other cases. When the reagent is applied, various colors will be brought out. Nickel is red, iron is blue, and lead is yellow.

The adsorption quality of various papers is different. For example, drops of nickel and lead on typing and mimeograph paper did not move in five hours, but on filter paper Whatman number 41 a good result was obtained in one hour; filter paper Whatman number 1 also produced excellent results.

For exhibition purposes strips were dried and mounted on heavy white poster paper.

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Separating Complex Substances By Chromatography

C. LEROY HEINLEIN

Assistant Principal, Gamble Junior High School, Cincinnati, Ohio

and F. M. MIDDLETON

Chief, Advanced Waste Treatment Research, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio

(MAY 1958)

Background

Many of the materials recovered from water using the carbon filter are very complex; thus, analysis is difficult. There are many different ways to separate chemical materials. An interesting and remarkable way is chromatography.

Chromatography designates a group of specialized and highly sensitive methods for separating a number of very similar substances. Chromatography works because of peculiar adsorption forces which are different for different materials. The following experiments will demonstrate chromatographic methods for separating the colored pigments that make up colored inks and chlorophyll. Scientists apply these and other methods of chromatography to research problems.

PART I. PAPER CHROMATOGRAPHY

Statement of Problem

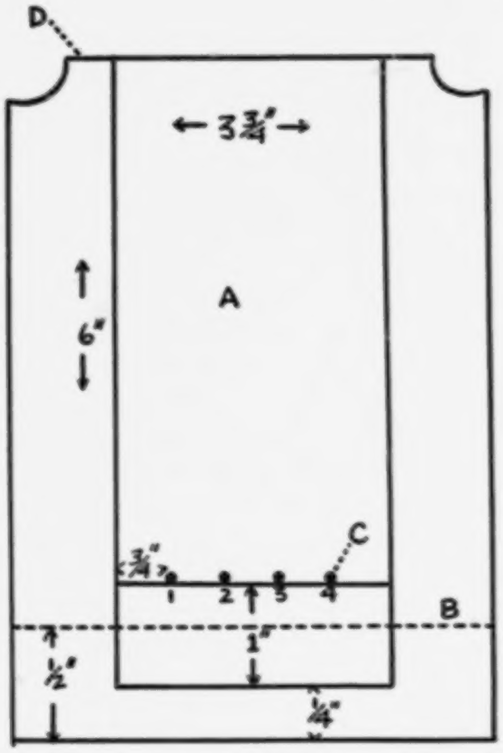
To demonstrate how colored pigments in inks can be separated by paper chromatography.

Materials

1. A quart fruit jar with lid
2. A strip of filter paper at least 1" wide and 6" long. Using a wider strip of filter paper, several tests can be run at once.
3. A solution of ammonium sulfate (prepare by dissolving as much ammonium sulfate in distilled water as will go into solution—approximately 75 g in 100 ml water)
4. Various colored inks
5. Rubbing alcohol

Procedure

A. Draw a light pencil line across the end of the filter paper about 1" from the bottom. Place a very small drop of each ink to be tested on the line so that the drops are ¾" apart. After the drop has been absorbed by the paper it should not be larger than a pea. (See Drawing 1)



Drawing 1. Arrangement of fruit jar for paper chromatography

A. Filter paper fastened to lid
B. Level of solution in jar
C. Ink dot
D. Jar lid (need not be screw type)

B. Attach the filter paper to the lid of the fruit jar with adhesive tape and adjust the paper so that it comes to within ¼" of the bottom of the jar. The lid need not be screw type.

C. Mix the following solution and pour it into the quart jar to a depth of ½":

10 parts of the alcohol
15 parts of the ammonium sulfate
75 parts of distilled water

(A thistle tube can be inserted through a small hole punched in the lid. Adding the solution through the thistle tube prevents splashing of the solution on the paper.)

D. Put the lid on the quart jar so that the end of the paper dips into the solution. The spots of ink should be near the bottom of the filter paper but not in the solution. Be careful that the paper does not touch the moist sides of the jar. Let the jar stand and watch as the liquid rises in the filter paper. What happens? The colors of the ink have been chromatographed. This has brought about a separation that might be quite difficult by other means.

Follow-up

Try several different blue inks. Try other colors of ink. Are all the components the same? Make collections of sample papers.

PART II. CHROMATOGRAPHIC SEPARATION OF LEAF PIGMENTS (Teacher Demonstration)

Statement of Problem

To demonstrate how colored pigments of chlorophyll can be separated by column chromatography. This is a modification of the procedure given in Linstead, Elvidge, and Whalley, *A Course in Modern Techniques of Organic Chemistry,* pp. 6-8. R. H. Burttschell, chemist at Robert A. Taft Sanitary Engineering Center, helped develop this modified procedure for columnar chromatography.

Materials

1. Fresh spinach leaves
2. Petroleum ether (boiling range 30°-70° C)
3. Benzene
4. Methyl alcohol
5. Ethyl ether
6. Filter paper
7. Funnel
8. Separatory funnel 250 ml
9. Erlenmeyer flasks 125 ml
10. Sodium sulfate, anhydrous
11. Filter flask
12. Water pump (aspirator for creating vacuum)
13. Glass tube ¾″ diameter, 18″ long
14. Glass wool
15. *Very fine* granulated sugar (box should say *very fine* on it)
16. Pipette or medicine dropper

Procedure

A. Preparation of Leaf Extracts. Blot dry two or three spinach leaves with filter paper and place in an oven at 32° C for one hour (air-dry overnight, if preferred). Remove, bruise by grinding in a mortar, and then soak with a mixture of 90 ml petroleum ether (boiling range 30-60°), 10 ml benzene, and 30 ml methyl alcohol.* Let stand until a deep green color is formed. Filter the solution through an ordinary filter paper into a 250-ml (or 500-ml) separatory funnel. Add 50 ml of distilled water slowly, allowing it to run down the sides of the funnel. Swirl funnel *very gently* two or three times and allow to stand for five minutes. Remove the lower layer and discard. Repeat this procedure three additional times. This is necessary to wash the alcohol out of the solution.

Emulsions are very likely to form and some of the yellow materials, carotenes and xanthophylls, are discarded with the emulsified water layer; however, ample material is left for the experiment and it is not worthwhile to try to break the emulsions.

Pour the upper layer into an Erlenmeyer flask and add about 20 g of anhydrous sodium sulfate (Na_2SO_4). Allow the mixture to stand for two hours, with occasional swirling. This step removes the excess moisture from the solvent.

Filter the solution into a 250-ml (or 500-ml) thick-walled filter flask. This removes the Na_2SO_4. Stopper the flask and connect it to an aspirator or other vacuum source (wear safety goggles). Warm the flask on a hot plate while shaking the flask continuously until only about 5-10 ml of the liquid are left. This evaporation removes the excess solvent (petroleum ether and benzene). (*Caution: Do not use open flame for evaporation.*) The extract is then ready for chromatographing.

B. Preparing the Column. A glass tube about ¾″ outside diameter is constricted about 1½″ from one end and cut off at the constriction, leaving a hole about ⅛″ or so in diameter. Pack in a small amount of glass wool—do not tamp hard. The tube is now ready for the packing. (See Drawing 2)

Weigh out about 30-35 g of very finely granulated sugar—do not use powdered or coarse granulated sugar. Break up the lumps in a mortar but *do not grind.* Add about 50-80 ml of petroleum ether, boiling range 30-60°. Swirl strongly to suspend the sugar and pour into the tube. The amount of sugar in the tube should approximate one-half of the length of the tube (8-10″). While it is settling tap the clamp holding the tube with a ruler. Catch the solvent running through the column and shake again with the sugar which was not washed out of the flask the first time. Add to the column and repeat until nearly all the sugar is in the column and well packed down. Always keep some liquid over the top of the sugar in the column; the surface of the sugar, once wetted, must never be allowed to dry out until the test is finished.

C. Running the Chromatogram. Let the solvent flow through the column until there is less than a

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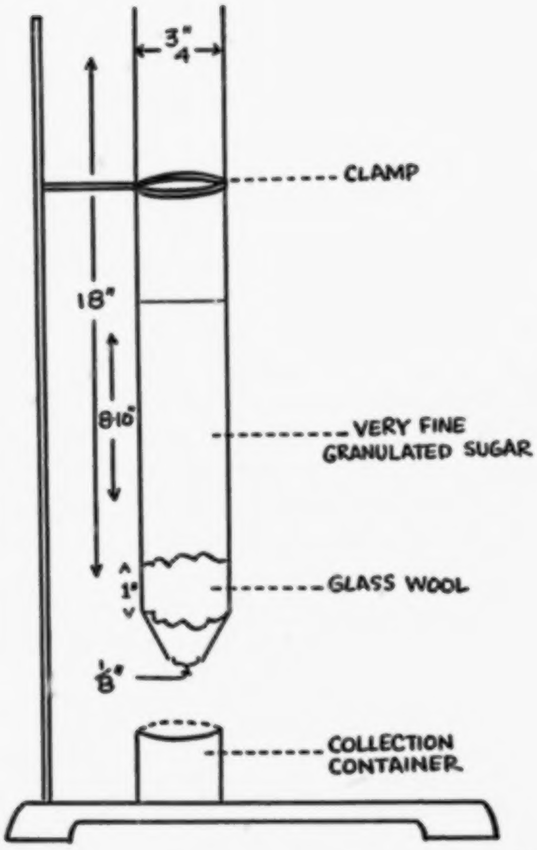
* CAUTION: Pouring and handling of all solvents should be done in a hood or in a well-ventilated room. Do not breathe the vapors and do not use near a flame.



Drawing 2. Arrangement of column for chromatographing leaf pigments

centimeter height over the surface of the sugar. With a medicine dropper or pipette add the leaf extract to the column, letting the solution run gently down the sides of the column so as not to disturb the surface any more than necessary. Let the top of the colored solution just reach the surface of the sugar and then wash down the walls again with 4 or 5 ml of petroleum ether, adding cautiously as before. Let this reach the surface of the sugar and then, *gently*, add enough petroleum ether to almost fill the column. Place a clean, numbered flask to catch the effluent and proceed with developing the chromatogram. Keep the column almost full of petroleum ether, adding more when the level drops to within about an inch of the top of the sugar column. Use a total of about 100 ml of petroleum ether after the leaf extract is added.

A light yellow zone quickly washes down and is caught in the first flask. This may not be noticeable if the sample is too small. Another yellow zone appears but proceeds very slowly, and there should be a zone of pure sugar visible between the two yellow zones. When the first zone is washed through the column, change receiving flask and catch the next fraction.

When the last of the petroleum ether is approaching the surface of the sugar add a mixture of 50 ml of petroleum ether and 10 ml of ordinary ethyl ether.** The second yellow zone is quickly washed out with this; as soon as all (or most) is out, change flasks again and catch a strong blue-green zone; when this is almost all washed out, catch the final olive-green effluent in a fourth flask.

This completes the operation. Observe the differences in the colors of the fractions. The first yellow fraction is a mixture of carotenes, the second yellow fraction a mixture of xanthopylls, the blue-green is chlorophyll-a, and the olive-green is chlorophyll-b.

For qualitative purposes the chromatogram need not be developed past the point where the zones have separated sufficiently to be visible to the eye.

Follow-up

1. Repeat using other green leaves such as grasses, geraniums, etc.
2. Repeat using autumn leaves of varying colors, or plants with colored leaves.

Applications

Paper chromatography, column chromatography, and many other kinds of chromatography are used to bring about separation of complex mixtures. Knowledge of the chemical identity and nature of materials is essential to help solve baffling problems. Often it is necessary to work with very small amounts of materials as with the small drop of ink. These chromatographic methods are used at the Robert A. Taft Sanitary Engineering Center to help separate and identify chemicals that appear in water in very minute concentration. These chemicals are associated with organic contamination of water.

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** Ethyl ether is very inflammable.

PART D
General Utility Ideas

Experimenting With Experimental Methods

H. SEYMOUR FOWLER

Professor of Science Education, The Pennsylvania State University, University Park, Pennsylvania

(APRIL 1952)

One of the primary functions of science teaching is the development in the student's mind of a healthy skepticism. The partial accomplishment of this function can be carried out particularly well in the ninth-grade general science courses. Almost any text devoted to general science is literally filled with statements of exact weights or lengths of things and individuals, of definite distances between objects, and of the composition of other objects given in percent. These designations of weight, length, distances, and composition are by implication the final word. These figures give us as teachers the ammunition for the development of the healthy skepticism in the student. The very nature of our students makes possible the accomplishment. A typical high school freshman is the epitome of the skeptic. It is at this level that the teacher can take advantage of both of the aforementioned characteristics and really make progress in the teaching of the experimental method.

One such instance in the author's experience comes to mind. The class was neither superior nor dull, although portions of both ends of the normal bell-shaped curve were represented. On the whole the class was of average mental ability.

In this case the class was studying a unit on water. The author of the text which was used in the class had listed the percentages by weight of water in various food substances. One of the boys in the class became skeptical of the flat statements of percentages. The author of the text had listed the water content of an apple as 85 per cent. This boy was convinced that certain varieties, in particular MacIntosh and yellow transparent, contained more water than did crab apples. A girl in the class said that she had learned in home economics that the water in an apple amounted to 90 per cent of its weight. With this remark she had added, "Which is correct?"

There was but one answer as seen by the writer. This was to admit that he didn't know. However, a lively discussion ensued when the class was asked, "How would you find out?"

One member of the class said that we could go to the local cider mill and find out how much cider was made from a bushel of apples. This suggestion was vetoed in short order by other members of the class who reminded the first member that cider consisted of more than plain water. Another suggestion for drying the apples met with an equally enthusiastic veto.

After other futile suggestions had been made, one member of the class suggested that the apples might be "burned" and still keep the ash. This method was approved by the class. A covered crucible was decided upon as a container. The class then decided on its method of procedure. This method follows:

1. Weigh crucible and cover.
2. Fill crucible with pieces of apple.
3. Weigh crucible plus cover plus apple.
4. Find the weight of the apple.
5. Heat the crucible plus contents until only ash remains.
6. Cool the crucible and find the weight of crucible plus ash.
7. Determine the weight of the ash.
8. Determine the percent of water in the apple by use of following equation:

$$\% = \frac{\text{Weight of Ash}}{\text{Weight of Apple}} \times 100$$

This procedure was carried out amid howls of protest throughout the school building when odors of burning apple found their way into neighboring rooms.

But now you say, as your students will also say: "What about the weight of the chemical elements which escaped in the smoke?" To this, we answer; "That gives you an opportunity to inject the idea of 'limitations,' an essential consideration in any scientific experiment."

In the case described here two students worked together as a team. Three apples were cut into pieces so that each team was provided with a portion of apple. The students seemed eager to disprove the experts and were anxious to compare results. The boy who believed that different varieties of apples contain different percentages of water tested his hypothesis during noon hours.

Here is an interesting activity for general science classes. It is an activity which employs materials familiar to the pupil, which demonstrates the experimental method, which uses real experience instead of vicarious experience, which proves that the textbook is not always an infallible source, and which helps to develop that healthy skepticism so essential in today's era of high pressure salesmanship and advertising.

Visual Aids and the Problem-Solving Exercise

JOHN H. WOODBURN

Chemistry Teacher, Walter Johnson High School, Bethesda, Maryland

(SEPTEMBER 1953)

THE INTRODUCTION of more problem-solving type classroom experiences is a goal that is attracting the increased attention of science teachers today. This doubtlessly follows from the emphasis that is being placed on the importance of giving our students a genuine appreciation of the methods and procedures of scientists. Many teachers believe that such an appreciation can be developed only in classroom activities in which there exists a problem-solving atmosphere. How can this atmosphere be maintained? Our professional literature reports many instances of creative efforts to provide answers to this question. Such efforts have been, for the most part, directed toward one of three areas. (1) Attempts have been made to refurbish old or compose new textbook materials so as to emphasize the techniques and conditions which accompanied the acquisition of information. (2) Another group of creative individuals have made many modifications in the design and administration of laboratory activities with the intent of making them real problem-solving experiences. Finally, (3) many instructors have reported rather fruitful efforts designed to record evidence of student growth in problem-solving abilities. The quantity and quality of the research that has been done in these three areas is noteworthy.

There appears to be a minimum of reported attempts to prepare audio-visual aids so designed as to encourage the maintenance of a problem-solving atmosphere in the classroom. There is but a minimum number of current educational films and a few adaptations from theatrical productions that do anything more than merely announce and proclaim the results of scientific enterprises. The exceptions do portray selected scientific episodes rather well.[1] The author of this paper contends that the producers and, especially, the script writers of educational films can improve their product if they will give more attention to the methodology of science. Educational films could well include a description of the origin of hypotheses including some of those that turned out to be fruitless. In the films already available that do present the testing of hypotheses, the script could well emphasize much more clearly the design or strategy underlying the experimentation. Many students appear to be totally näive in sensing the strategy and limitations inherent in an experimental test of an hypothesis.

The second phase of the thesis that underlies this paper is directed toward classroom teachers. With a 35-mm. camera and a minimum amount of photographic experience, a teacher can provide himself with aids that are exceptionally useful in maintaining a problem-solving atmosphere. Much of this usefulness stems from the adaptability of the aid. Many teachers rightfully retain their own version of what are the methods and procedures of science. Some teachers deplore the identification of stereotyped steps while other equally sincere teachers think they can sense a definite procedural pattern in nearly every episode in science. The validity of either of these points of view is not the question here. The significant point is that either view is difficult to put into practice in the classroom without effective aids to learning. Students, in general, are not accustomed to approaching a topic in science with a problem-solving attitude. In some instances they actually resent having to "think their way out" of a perplexing and frustrating circumstance. Teachers who are trying to add the problem-solving type of activity to their repertoire need every aid to learning that is available or can be made available.

The first phase of this type of teaching involves getting a specific problem identified to the students or posed before them in a realistic and not too

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[1] This has been a prime objective of the NSTA Motion Picture Committee in the teaching films they have excerpted thus far.

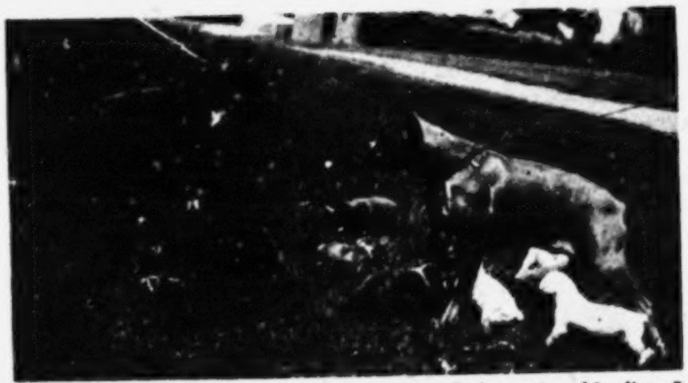


FIGURE 1. Do the three white puppies belong in this litter?

esoteric manner. The author was able to photograph a pair of pedigreed Boxer dogs and their litter which included three all-white or nearly all-white pups (Fig. 1.). The discrepancy between the coat color pattern of the parents and offspring immediately poses a problem before a group of students. A more esoteric example grew out of the generally accepted information that rose comb in chickens is dominant over the single-comb trait. An agriculture student obtained some single-comb hybrids from a cross between what he thought were purebred single-comb Leghorn hens and a Hamburg rooster. Photographs of these parents and their offspring provided slides which, combined with the textbook presentations, produced a perplexing situation.

In another case, the author photographed a sow with her litter of pigs (Fig. 2.). This slide immediately conflicts with the "like begets like" concept. Analysis of the facts evident in the slide and the consideration of conditions under which this litter was produced together with generally accepted facts concerning the inheritance of coat color in swine, duplicated with data-gathering phase

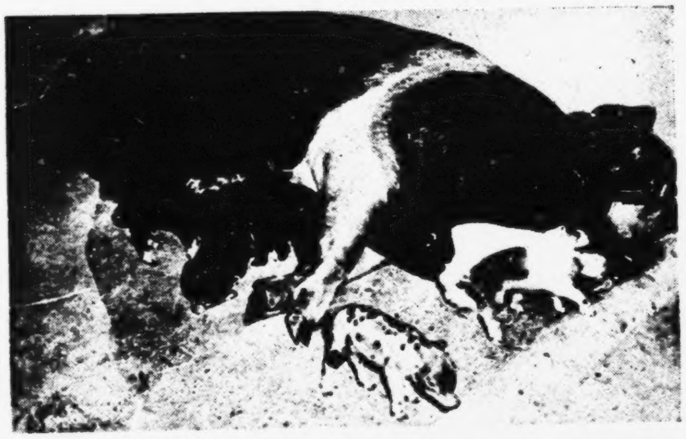
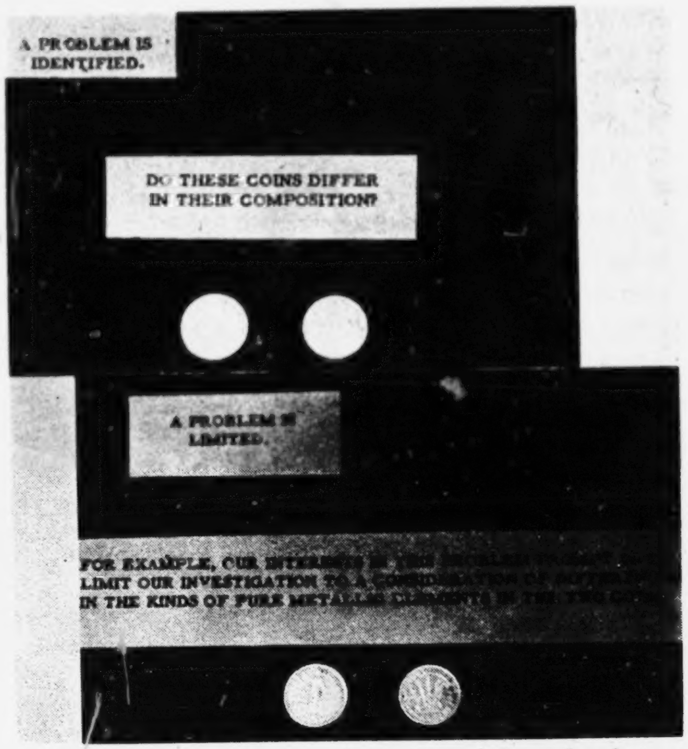


FIGURE 2. If "like begets like", what must the male parent of these pigs have been like?

so evident in many scientific episodes. These data practically lead the students to raise the question of whether or not the litter could have been sired by more than one male hog.

If an instructor chooses to present a more stereotyped interpretation of the methods of science, he can prepare such slides as are shown in figure 3. The complete series of these slides was designed with the single objective of portraying the basic strategy of analytical chemistry. Provision was



A PROBLEM IS IDENTIFIED.

DO THESE COINS DIFFER IN THEIR COMPOSITION?

A PROBLEM IS LIMITED.

FOR EXAMPLE, OUR INTEREST IN THIS [illegible]
LIMIT OUR INVESTIGATION TO A CONSIDERATION OF [illegible]
IN THE KINDS OF PURE METALLIC ELEMENTS IN THE TWO [illegible]

FIGURE 3. A problem in chemical analysis reduced to stereotyped "scientific method" steps

made for a minimum amount of student participation. The plans in connection with this series of slides include a second problem involving differences in the composition of two other coins that are almost identical in general appearances but differ in composition. Two references in the local library differ in regard to the nature of the metals used in the wartime Jefferson nickels. This apparent breakdown of the traditional "consultation of an authority" encourages the students to try another type of solution to the problem.

The 2 x 2 color slide is effective in aiding students to visualize the species and materials with which investigators have worked. The author has come to realize how little meaning bare words carry in attempting to describe Leghorn and White Silkie chickens to students from non-farm backgrounds. An understanding of the inhibitor gene effect as discussed in the textbook, however, hinged on the students' conceptions of these two breeds of chickens. Exhibitors at the local State Fair cooperated in making a slide available in which these two breeds can be compared (Fig. 4.).

The nature of the genes that are responsible for the transmission of flower color in four-o-clocks presents an exceptionally rich teaching situation when presented by means of 2 x 2 color slides. A slide was made which showed all of the data related to inbreeding each of the six phenotypes: red, white, yellow, pink, orange, and lemon. By carefully masking portions of the slides with opaque tape it was possible to dole out data to the class by revealing separate portions of the whole slide. This technique enabled the instructor's script to include such questions as—What is the most logical analysis of the results of this cross? What modifications should we now make in our tentative hypothesis in the light of these additional data?

Some of the desirable reality of slides of the actual materials used in the solution of a problem may be sacrificed at certain phases of the teaching exercise in order to save some of the time required to arrange the actual materials for satisfactory photography. The origin and testing of hypotheses may be portrayed by slides prepared from photographed diagrams and charts. Figure 5 shows such a slide. The problem that was involved here was sex-linkage as exemplified by the barred feather pattern in chickens. The slide shown in Figure 5 contains the gene symbols that were necessary to provide a logical observation of the crosses as diagrammed. Differences between poultry and human in respect to the transmission of the sex chromosomes create a good problem-solving situation. Given data related to the transmission of human color-blindness, students who have developed the sex-linked concept as exemplified in poultry should be able to sense the genetic pattern of inheritance of color blindness.

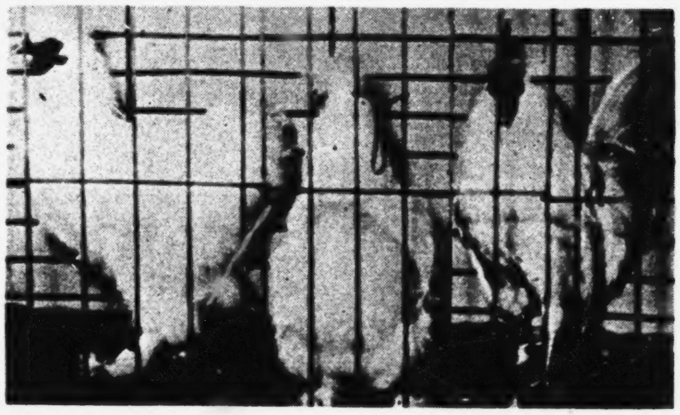


FIGURE 4. Silky versus normal feathers, yellow skin versus lead gray, and pea comb versus single comb

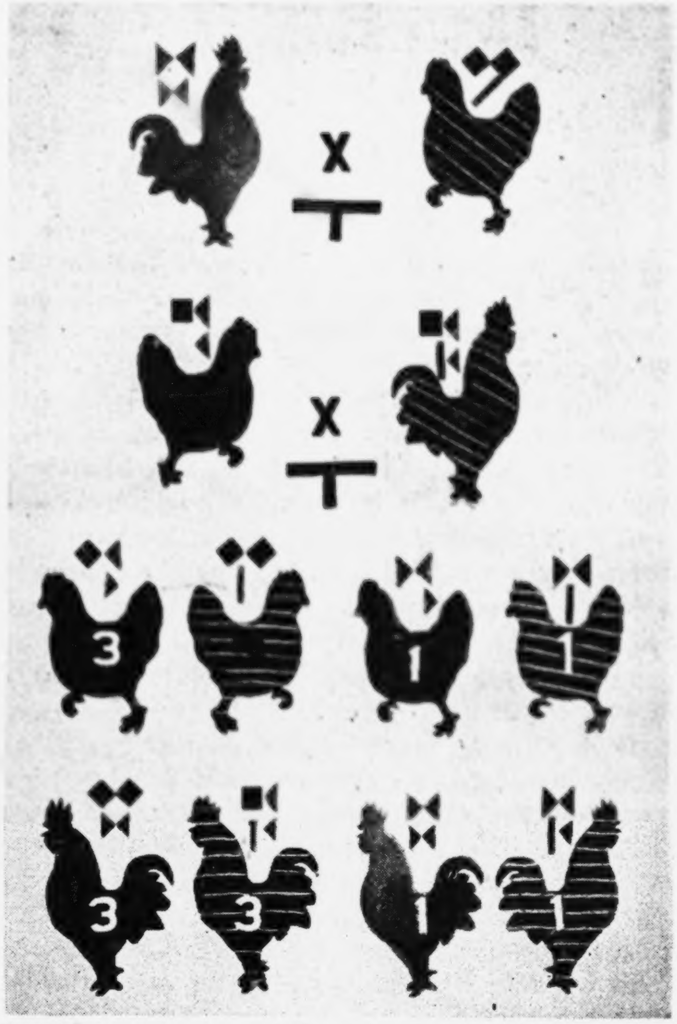


FIGURE 5. A genetics problem portrayed diagrammatically and the diagram reduced to a 2 x 2 color slide

If a science teacher stays alert to scientific enterprises being conducted in his community, quite often he is able to acquire especially useful 2 x 2 slides. As an example, the author was able to make a photographic record of a project in which colchicine was used to produce tetraploid watermelons which, in turn, were crossed with ordinary diploids to produce seedless fruit.

The author feels that he has but scratched the surface of the total contribution that audio-visual aids may make toward encouraging the problem-solving type of teaching exercise. Rather than having a film merely announce the volcanic origin of Crater Lake, would not the film be more valuable if it portrayed the precise observations that produced conflicting hypotheses and then followed through on an examination of evidence leading to the eventual elimination of one and the retention of another hypothesis? A film or series of 2 x 2 slides that portray the evolving identification of the relationship between plant auxins and phototropism could do much to illustrate in a genuine fashion how scientists work.

Ninth Grade Science Research

ANNE E. NESBIT

Head of Science Department, South Junior High School, Pittsfield, Massachusetts

(MARCH 1959)

Curiosity! Imagination!! Patience!!! Taken individually these nouns may be essential tools for success in a variety of occupations. Taken together they are not necessarily restricted to scientists, but they certainly are recognized as being absolute necessities in his "tool chest" if he is going to meet with success, be he a future science teacher, researcher, or technician. Though all this is realized by today's science teachers, the big questions confronting us are:

1. How can we supply these "tools" to our students if they don't already possess them?
2. How can we sharpen these "tools" for those who already give evidence of having them?

My story begins in September, 1953 with the opening of our new junior high school in which science was being offered to students as a major subject for the first time in the history of our city. In addition to science, the school program called for a science club as an extra curricular activity. As chairman of the science department, I was elected to direct the activities of these future "scientists(?)." Students interested(?) in science were invited to join. This invitation was my first big mistake! I quickly observed that most of my members were people looking for spectacular entertainment. Try as I might to interest them in an over-all problem, I continually met with failure. There were however in this group, three students curious and imaginative enough to proceed with research of their own.

My work with these three very interested students made it obvious that a 40-minute club period, twice a week, was not sufficient time to gather necessary materials, experiment, clean-up and, at the same time, get anything of value accomplished. Thus the principal agreed to give the class two extra periods—these supplanting those formerly used as a two-period elective (as typewriting or shop).

The following admission standards were devised:

1. The student must, as an eighth grader, show both an interest and aptitude for science.
2. The student must have demonstrated his ability to cooperate and get along with other people.
3. The student must be willing to put into his project whatever extra time may be necessary. (This requirement was important to us for it meant release from the obligation of seeing that a pupil was on this or that bus.)

The next step was to set a limit of 15 students to the class.

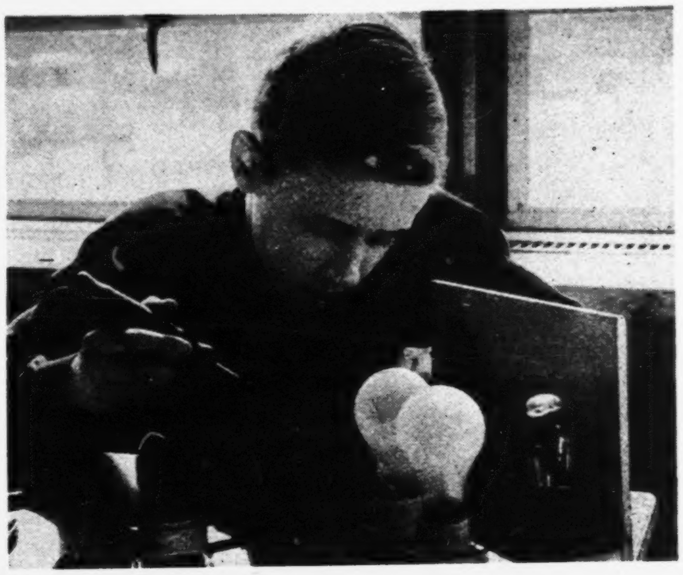
Growth of Idea

The first two or three periods in September, 1954, were devoted to orientation. The nature and purpose of the class were reexplained.

Some students already had an idea for a project; however, most had yet to decide on one. Individual pupil-teacher consultations were held and, with the help of project ideas from NSTA and various science books, a project was decided upon by each student. Individual "research" was

Experimentation begins.

VERA V. FIELDING PHOTO



begun. And here is where my next mistake was made! I never should have let these boys and girls begin to "swim" in such deep "water." Fifteen voices were asking me fifteen different questions all at once. My head was in a whirl and I resolved never to let this happen again. As time went on, I discovered that many questions were peculiar to the entire class, as how to light the Bunsen burner. I also discovered that, at the most, I could only help about six pupils during the period. As a result, the other nine questioning minds patiently waited until the following lesson hoping I would get to them.

By the close of the year, my results with this first class were as follows:

A. Nine students became really interested in some phase of science and, considering their slow start, had accomplished something of value.

B. Three students had shown some progress but their interest in science, at this point, was definitely questionable.

C. Three students had accomplished nothing and admitted that they were not as interested in science as they thought they were.

Note: I like to feel that this realization was of value to them in selecting their high school program.

The most important outcome of the entire year was the realization that my idea was a good one and that, with changes, it could be made to work.

September, 1955

The science research class was now twenty-four in number. The increased enrollment resulted from extreme demand for the class from students and parents alike. Another teacher in my department assisted me with the group and we each took twelve students. The following changes were made from the previous year:

1. Closer supervision of project choice. Each student was required to write out his plan of action, why he had chosen the project, and what he hoped to accomplish with the project.

Result: Much less shifting of project interest, but still too much to satisfy me.

2. Students working in identical or related fields were instructed, as a group, on the various lab techniques which might be required.

Result: Lessened demand on teacher for attention and hastened project work.

VERA V. FIELDING PHOTO

Collecting the data.

3. A requirement was set for each student to keep a class log of his work for each period. If nothing was accomplished, he was to write for that date, "nothing done!"

Result: There was much less wasted time.

4. Periodic Seminars. Each student stood before the group to tell the nature of his experiment and what he had accomplished to date.

Result: a. Stimulated students to accomplish something in order to avoid embarrassment.

b. Other students were able to suggest how the speaker might improve his work or solve his current problem.

c. Thirty speakers took 12 periods of time or three weeks away from project work. This was not good!

5. Special Science Research Report Card: Each student was evaluated on various science qualities.

Result: Spurred better work but report was so complete that parents questioned why such a report could not be given in every subject. As this was impossible, I had to abandon this idea the following year.

6. Library Improvement. A special science research library was organized. The school purchased many valuable books for me, and the science teachers in the school contributed their own personal books. This library is located in a glass cupboard in my classroom and is locked, at all times, except when in use.

Result: Science prestige for the students but—more important—valuable aids for the teacher.

7. Science Fair. Each student was required to submit his project, regardless of its condition, for the Fair. The science research group formed a special section of its own and these students competed among themselves. This was done in order not to discourage other school students.

Result: There was good, sound competition between each other. Excellent projects were completed, many of which had carried the student into college science. The nature of many of the projects was so complex that the school officials and general public were amazed that so much could be done by a ninth grader.

8. Newspaper Publicity. A feature writer for our local paper visited our class, took pictures of their projects and wrote a very interesting column describing what she saw. This, incidentally, was done just before the Fair.

Result: This awakened Pittsfield to what we were trying to do, and it also served as an excellent advertisement for our Fair. The class not only gained marvelous publicity for itself, but it also won the admiration of many industries in and around Pittsfield.

In spite of all the progress we had made this year, there was much yet to be done. I still was not satisfied with the speed with which research moved forward. I also felt that much valuable time was still being lost in really "getting underway." I decided I must strengthen these weaknesses the following year.

September, 1956

The year opened in our school with the formation of three honor classes—one each in English, algebra, and science. I was assigned to teach the science honor class. Thus, I decided to make this class also my science research class. In an effort to improve orientation, the following practices were developed:

1. The showing of current films:

Result: Students were quick to see that science research truly calls for curiosity, imagination, and patience! In addition, they saw the importance of being accurate and of being tidy. They also saw how some first-rate scientists solve their problems.

2. Following the films, twelve periods were devoted to instructing the *entire* class, as a unit, on lab safety, general lab techniques, lab cleanliness, and good housekeeping.

Result: There was now no time lost in showing individual students how to light the burner, dilute acid, make up solutions, clean glassware, and other tasks.

3. A set of twenty-seven elementary, short-range, science problems were next submitted to each student. The problems were evenly divided among the fields of biology, chemistry, and physics. The student was permitted to select any *one* problem for solution. Upon its successful completion, he was required to select still another problem but this one had to be in a field different from his first choice. Having completed this, he was able to begin his long-range project.

Result: a. The student learned the importance of a well controlled experiment.

b. He acquired skill in designing and successfully carrying out an experiment.

c. He learned how to properly gauge his time.

d. He became acquainted with all the tools of the laboratory—textbooks not excluded.

e. These small experiments gave me an opportunity to raise thought-provoking questions relative to each experiment. This proved to be a wonderful way to arouse interest in a long-range problem.

f. Many students who thought they were definitely interested in one field of science, suddenly became interested in the field of their second problem. In this way I gained many researchers for physical science which I would otherwise have lost to biological science. Not only that, but once having started their long-range problem, not one student wished to change his project. This was, indeed, an accomplishment.

I also continued with the daily report logs inasmuch as they had proven so successful the previous year.

We again had our Fair and once again the science research section brought superlative praise from all who visited it.

September, 1957

With the problems of proper orientation and stimulation solved, the next problem to consider was whether or not to drop from the course anyone who showed, from the start, the inability to design and plan out an experiment. These students will never make research scientists, but they may make good technicians. For this reason, I question the wisdom of asking them to leave. My answer to this problem will not come until

I have a chance to observe the future paths of the students of my first two classes. (These are now high school seniors and juniors respectively.)

General Summary

Science research can begin on a ninth-grade level. Success can be obtained by:

1. Proper scheduling. A double period is a necessity.
2. Proper selection of students. We have found our admission standards very satisfactory.
3. Proper orientation
    - a. Films. Use current subjects and vary the films.
    - b. Training for entire class in basic laboratory fundamentals.
    - c. Successful completion of two elementary short-range science problems.
4. Proper stimulation
    - a. Daily logs.
    - b. Seminars.
    - c. A science fair entry.
5. A generous supply of resource information
    - a. Textbooks, both high school and college.
    - b. Laboratory manuals, both high school and college.
    - c. Pamphlets offered for the asking from various industries and science professions.
    - d. Project ideas and samples of successful projects. These may be obtained from the National Science Teachers Association.

Evaluation

Though not enough time has elapsed to permit an accurate evaluation of the class, I can cite the following as indicators of success:

1. Former students keep returning after school to learn what their successors are doing.
2. Former students have organized a high school science club in order to further the projects begun in our school.
3. There are constant inquiries from seventh and eighth graders and their parents as to admission requirements to the class.
4. With one exception, no student in the last three years, who has started the class, has ended as a failure as far as science research is concerned.

In conclusion, let me say that I believe I have found a way to develop the curiosity, imagination, and patience of potential, future scientists. I have found that, in the majority of cases, these qualities are nurtured but can, on occasion, be planted in students.

Analysis of Independent Study Projects

DONALD WYNANT HUFFMIRE

Instructor, Management Science, Monmouth College, West Long Branch, New Jersey

(APRIL 1962)

STUDENT PROJECTS can be separated into three main categories: problem work, special reports, and problem solving.

Problem-Work Group. A problem-work project may be assigned by the teacher for a particular purpose, or it may be chosen by the student who tries to confirm a known principle either by following directions or by employing an uncreative procedure without the use of scientific method.

Examples of problem-work activities are found in most workbooks, syllabi, laboratory manuals, handbooks, and textbooks.

Problem-work exercises have their place in science teaching. The history of science is the content of our present science courses. Therefore, to more effectively teach what is included in the content, problem-work activities should be assigned to the students.

Special Reports. Special reports are individual study projects in which the student summarizes scientific journal articles and books on earth science. They also include library research reports explaining principles set forth in the textbook.

Problem-Solving Group. Problem-solving projects are those in which statement of the problem is a creative act by the student. Through this method, he forms certain concepts by the use of different tactics and strategies of scientists, and new concepts are formed as a result. In solving problems, the scientist continually seeks concepts and conceptual schemes to help him better understand the universe. The end result of problem solving should be the evolvement of one or more new problems that are developed.

Three main categories of problem-solving projects which the student may undertake are: (1) the problems suggested by research as it is carried on in industrial and university laboratories, (2) ideas borrowed from historical science experiments, and (3) ideas suggested by science teaching.

Representative Projects

Problem-Work Group. Many of the projects completed by the students at New Hartford Central School were in the problem-work category. The student confirmed principles evolved by authorities. He did not carry out a scientific investigation. He was not required to be creative. He probably did not develop much in self-direction or independence.

The problem-work projects were either assigned by the teacher or initiated by the student. The teacher-initiated projects were taken from various laboratory manuals and handbooks. The student-initiated projects were end-of-unit projects and science-congress projects. End-of-unit projects were required for most geology units, as well as for the units on astronomy and meteorology. In addition, each student in the earth science classes was required to do a science-congress project on his own volition.

A typical, laboratory-manual exercise can be illustrated by a student project on a study of lakes. Several topographic maps were studied showing lakes formed by various physical agents, such as running water, ground water, glaciers, wind, waves, and currents. The student answered the questions in the laboratory manual pertaining to the maps through his knowledge of earth science or reference sources. In this exercise, explanations were given by the student on the following topics: the various physical agents responsible for lake formation on each topographic map, why lakes are larger at lower elevations than at higher levels, the geological history of the particular area, the scale of the map indicating the contour interval and map area, the agricultural suitability of the area, and the probability of a large or small population in the area.

Other related exercises included the study of various categories of rocks and minerals according to their physical properties, the analysis of topographic maps illustrating important geologic formations produced by running water in plateau regions, the construction and reading of contour maps, the study of differences in geologic structures, the construction of a planisphere, analysis of a weather map, determination of dew point and relative humidity, and the climate of the United States.

For the end-of-unit projects of the problem-work variety, the student made models or charts to illustrate some principles of earth science discussed in the text, performed experiments on some aspect of the unit that interested him, or wrote a report on some principle explained in the unit.

Examples of end-of-unit projects included a model of a glacial trough with hanging valleys, models illustrating controur plowing, clay models of fold and fault earth fractures, models of dinosaurs, models of deltas showing distributaries, relief maps made from topographic sheets, a rain gauge, an anemometer, a solar furnace, and a hair hygrometer. They also included such experiments as determining the velocity of rain drops, forecasting weather with an electric barograph, preventing soil erosion caused by running water, observing spectra with a shoebox spectroscope, determining the permeability of different soils, making indium compounds, making a sextant and finding elevations with it, and observing the changes during the corrosion of an iron nail.

Science-congress projects in the problem-work area were based only on library research and not on observations and experiments. For example, a project on volcanic formations, showed a two-level model of volcanic formations and a cross-section diagram of a volcano. The upper level of the model showed two volcanic land forms as found on the surface of the earth, a volcano and a domed mountain. The lower level showed the rock structure of the earth beneath each formation by using drawings on a poster board. The student numbered each part on the volcanic cross section and prepared a chart which referred to these parts by number. Charts showing volcanic belts and volcanic classifications were included with the project. In his report, the student explained the formation of the structures and the geological history of the area, depicted the present rock structure, and gave a scientifically based prediction of the future structure of the area.

Other science-congress projects included: a petroleum-drilling apparatus; a large model to show flood control of the Mississippi River system; models to explain and illustrate the life cycle of a river; a model gyroscope; a project on balloons; a solar distillation apparatus; models, diagrams, and pictures to explain the birth and development of the solar system; charts to explain the ocean currents; a shell collection and charts to explain the parts and how they were formed; a model seismograph; prehistoric fish; a study of metals; and examples of coral and charts to explain the formation of coral reefs and atolls.

The problem-work projects did not meet the standset forth in the evaluative criteria with regard to using the techniques and methods of the scientist. These projects were not suitable for scientific investigations. They did not require the formulation testing and retesting of hypotheses to solve problems during the investigation. Data were not collected by direct observation and experiments, nor were they checked and rechecked. Conclusions and concepts were not based on empirically collected evidence.

Undoubtedly, some creativeness was required for the problem-work projects. Little creativeness is needed, however, unless the student states his own problem; has a scientific problem to investigate; makes novel adjustments; and is original in organizing data, synthesizing observations, collecting information, designing equipment, deriving new problems, and drawing conclusions.

The problem-work projects were certainly important to the students individually and much was gained from the experience. Some self-direction and independent thinking were needed, but it is obvious that not much is needed for a problem-work project where the problem is stated and the directions for procedure are given in advance. It is apparent that a student will gain more in self-direction and independent thinking if he must develop his own methods of procedure, learn the necessary working skills by himself, set up his own experiments around his own hypotheses, and question authoritative statements when he has data to support his contentions. A problem-work project does not give the student the opportunity to express the mental qualities needed

FIGURE 1. Volcanic formations.

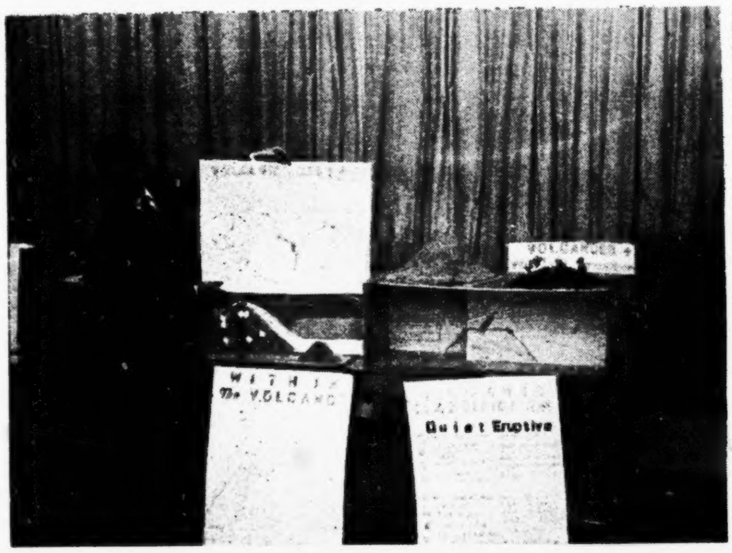
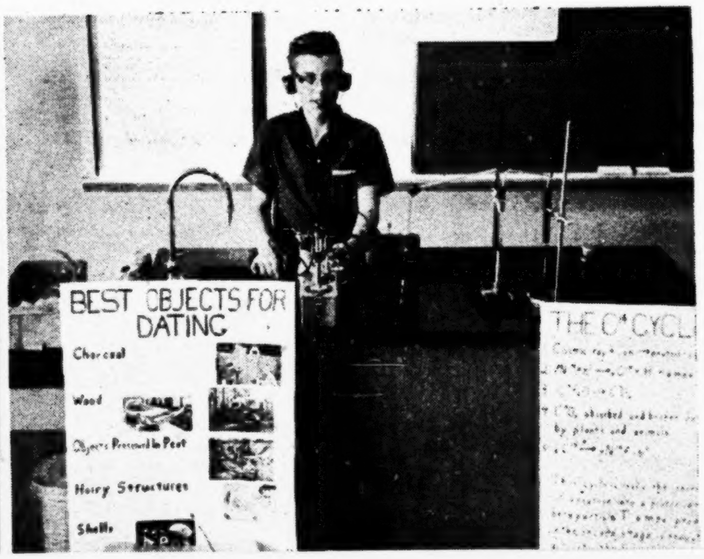


FIGURE 2. Detection of radiocarbon.



for scientific research.

The major results relative to learning of the problem-work projects were to give the student more knowledge about a particular area of earth science, to help the student better understand earth science principles discussed in the textbook, to help review known principles, to give the student experience in writing a report, to increase the interest of the student in earth science, to provide the opportunity to translate knowledge into applications, to provide for certain students' lack of ability for original research, and to provide for learning at the student's own pace.

Special Report Group. Special reports were assigned to give the student the opportunity to read science literature at his level and summarize his reading.

Among the special reports assigned, were articles from various scientific magazines[1] and books, all on earth sciences. End-of-unit reports were also submitted in lieu of models, charts, and experiments.

Examples of magazine article reports included discussions of radio astronomy, petroleum drilling, earthquake waves, balloon astronomy, rocket astronomy, and the life of sand dunes.

Each student read and gave reports on at least one book pertaining to earth science. One such report described the earth, its internal structure, the crust, seismology and its importance in understanding the internal structure of the earth and various methods to determine the age of the earth.

Other book reports were on such topics as radiocarbon dating, atomic energy, oceanography, rocks and minerals, stars, rockets, the sun, relativity, the weather, the historical development of the concepts of molecular structure, and some biographies of noted scientists in many fields.

End-of-unit reports are similar to scientific journal and book reports in that they are devoted to summarizing and writing a report on earth science topics. These reports required reference to books and journals. One such report concerned the formation of uranium deposits that were formed in the Colorado Plateau.

Some of the possible values of the special report are: to give the student more knowledge about a specific topic of interest in earth science; to indirectly teach him the tactics and methods of the scientist; to "catch" the climate of accuracy, carefully detailed work, and essential honesty of the scientist's efforts; to learn how scientists develop their conceptual schemes and evolve new problems; to show that unsuccessful, as well as successful experiments, are fully reported; to learn the methods by which scientists reshape material and ideas to reach major conclusions; to develop appreciation for scientific achievement; to uncover possible projects for future investigations; to answer questions he may have about a certain subject; to provide for individual reading differences by allowing students to read articles or books at their own rates of speed; to increase the scientific vocabulary of the student; to teach the student to prepare a clear, comprehensive, well-written report on an article or book; and to help the student realize that he is capable of reading and understanding challenging scientific literature.

Problem-Solving Group. A few of the unit and science projects were scientific investigations, and the students involved in the projects achieved the objectives of science teaching.

One end-of-unit project developed into a problem-solving project for a student. He made direct observations of the Willowvale Ravine and compared his observations with a topographic map of the area. He questioned the accuracy of the representation of the ravine on the map. He then collected data by direct measurements of the ravine and made his own topographic map.

In addition to changing the topographic map of this area, the student collected rock samples from the ravine and identified them by their physical properties.

One problem-solving science-congress project was on radiocarbon, and it is shown with the instigator. The student designed an apparatus which could be used to determine whether organic substances, such as leather, charcoal, and wood have radiocarbon in them. From his library research, the student learned that radiocarbon, Carbon-14, is formed in the atmosphere by cosmic rays. On entering the atmosphere, the cosmic rays undergo various transformations, one of which results in the formation of neutrons. These change Nitrogen-14 atoms into Carbon-14 atoms and protons. The radiocarbon unites with oxygen to form radioactive carbon dioxide in the atmosphere. Plants absorb the carbon dioxide in food, and animals eat plants. Therefore, all organic matter contains some radiocarbon. To indicate the presence of this radiocarbon, the student burned samples of each of his materials. He obtained a stream of pure oxygen by combining hydrogen peroxide with manganese dioxide, and burned the materials by heating them in oxygen. The slightly radioactive carbon dioxide thus formed was then passed through a partially shielded counter chamber. The Geiger-counter readings of this chamber were then compared with the counter readings from a similar chamber without the carbon dioxide in it. The results indicated that the objects burned contained radiocarbon. The student deduced that the radioactivity came from the carbon and not from the oxygen, because his research convinced him that the oxygen which he had prepared was stable.

In the problem-solving projects, the students used the tactics and strategies of the scientist; expressed creativeness; and demonstrated individual growth in knowledge, self-direction, independent thinking, and the mental qualities of the scientific investigator.

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[1] *General Electric Review; Scientific American; Think* Magazine (published by IBM); and *National Geographic.*

In the radiocarbon project, the student devised an ingenious apparatus to show experimentally that there was radiocarbon in the organic materials he burned. Since the answer was already known in advance, his main problem was devising his apparatus to prove it. In designing the apparatus, the student used the inspiration method. He advanced through the preparation stage by reading all he could on the subject. An essay submitted in class indicated that he also experienced the incubation and illumination stages. The investigation was carried out well. The data were accurate. He tested and retested his hypothesis. His observations were verifiable. He kept a log book and wrote a report which included a bibliography. New problems suggested to him were methods to obtain purer samples, methods to better purify the gas during its passage, and procedures with which he could arrive at rough dates with his apparatus.

Conclusions

In my classes, the project requirements for the year are set forth during the first few days of the semester. The student is first orientated to undertake independent study projects in science. The words "science" and "project" are defined. The objectives of science teaching are explained. The projects which the student can undertake are mentioned. The learning values of each type of project are discussed. The evaluative criteria are explained for a scientific project.

From these discussions, the student knows what is expected of him. The objectives of the course are clearly outlined. The value of projects in achieving the objectives of the course are understood. The student knows the goal of a scientific investigation.

Each year, a few students will develop the unit and science-congress projects into problem-solving projects. They will carry out scientific investigations. They will achieve the objectives of science teaching. They will learn by direct use the techniques and methods of the scientist. They will use their creative talents to state their problems, develop their hypotheses, design their equipment, make their observations, classify their data, and draw their conclusions. They will develop the mental qualities of the scientist—clarity of mind, imagination, skepticism, thoroughness, intellectual honesty, and respect for the discovery of truth.

Next Steps in Evaluation

GEORGE W. ANGELL
President, State Teachers College, Plattsburgh, New York

and **WILLIAM W. RASOR**
Instructor, Science Education, New Paltz State Teachers College, New Paltz, New York

(DECEMBER 1950)

AN EIGHTH-GRADE science teacher was determined to help young people learn the methods of science. Through short discussions and examples he had been assisting students in identifying and questioning a variety of dogmatic statements made by various members of their group. The students had listed a number of things which they believed as true. They had previously discussed the meaning of such terms as facts and superstitions. Facing the pupils now was the problem of determining which of their beliefs were sound and which were not. Which of these simple beliefs could be supported by facts or by experimental evidence?

These pupils had not yet participated in activities specifically designed to develop an understanding of the experimental method. In order to set the stage for a discussion which would acquaint them with fundamental concepts involved in experimentation, the instructor had decided to start the class hour with a short quiz. This quiz, consisting of three items taken from the previous year's final examination, was presented to the students in the following form:

> Many of us disagree on the statements we have read and discussed. Some of us believe the statements to be true and others of us believe the statements to be false. One way to determine whether or not the statement is true or false is through experimentation.
>
> John, Mary, and Carl suggested the following experiments in order to gather evidence to determine the truth or falsity of the statement: "The chewing of gum cleans the teeth."
>
> *Will the experiment suggested by John, Mary, or Carl enable us to decide the truth or falsity of the statement?*
>
> **Directions:**
>
> A. Quickly read the experiments suggested by John, Mary, and Carl.
>
> B. After reading the three experiments, reread John's experiment and put an "X" in the box labeled YES if you believe John's experiment will enable us to decide the truth or falsity of the statement. If you do not believe it will enable us to decide, put an "X" in the box labeled NO.
>
> C. After you have finished marking the experiments, reread each experiment and tell why you decided it should be marked either YES or NO. Your statement should be well written. Use brief sentences that are very easily understood. Be sure to tell all of your reasons for saying either YES or NO.

John's Experiment

Select at random 20 people and ten judges to participate in the experiment. Divide the 20 people into two groups, A and B. Have the judges examine the teeth of the 20 people to determine cleanliness and then have the judges pass out gum to each of the people. Have the 20 people chew gum for two hours. Have the judges examine teeth at the end of two hours to determine if the gum chewers have cleaner teeth.

Mary's Experiment

Select at random 20 people and ten judges. Have the judges examine the teeth of the 20 people to determine the whiteness of the teeth. After the judges have left, equally divide the 20 people into two groups, A and B. Have one group chew gum for two hours. Have the judges come back in at the end of two hours and again determine the whiteness of teeth to see if gum chewers' teeth became whiter to a greater extent than those of non-gum chewers.

Carl's Experiment

Select at random 20 people and ten judges. Equally divide the people into two groups, A and B.

> After the judges have left, have one group chew gum for two hours. Have the judges come back in at the end of two hours and compare the cleanliness of teeth of gum chewers and non-gum chewers to see if those chewing gum had the cleaner teeth.

After the pupils had responded to the quiz items the papers were collected, and the discussion which ensued is partly recorded here.

Richard: "I don't think any of the experiments were any good because gum does more damage to the teeth than good."

Norman: "I think the same thing because sweetness of gum causes a coating on the teeth and causes the teeth to decay."

Robert: "Most judges can't remember how clean the teeth were before they left the room."

Robert: "The judges had to remember whose teeth were cleaner, and if they were biased they would not judge fair."

Dick: "Judges don't know what is going on when they come back to see what teeth are the cleanest. Just tell them to examine the people, then let them out of the room. When they come back let them examine the ones who have chewed the gum and those who haven't to see who have the cleanest."

Richard: "If you have white teeth or have a film on them, just chewing gum for two hours won't change them. They will stay the same."

Teacher: "Chewing of gum does what?"

Group Answer: "Cleans teeth."

Teacher: "Are we trying to decide if chewing gum is good for the teeth?"

Joan: "No."

Teacher: "What is it we are trying to decide?"

Allen: "Whether it cleans the teeth or not."

Teacher: "Richard, do you remember what you said in the beginning about the experiments?"

Richard: "None of the experiments were good because chewing gum is not good for the teeth."

Teacher: "Could we use that for saying the experiments are not any good?"

Group Answer: "No."

Teacher: "Norman says sweetness causes the decay. Does this enter in the judgment of whether or not these experiments are good?"

Ralph: "We want to find out if they are clean."

Teacher: "If a tooth is decayed does it mean the tooth is not clean?"

Norman: "Not necessarily; clean teeth can be decayed."

Teacher: "I wonder if we can see the fact that chewing gum may or may not cause teeth to decay? Would that have anything to do with our experiment?"

Robert: "It would not right away."

Teacher: "We are looking for what in the experiment?"

Norman: "Whether gum cleans teeth."

Teacher: "What do you think is right and what is wrong with John's experiment, if there is anything right or anything wrong?"

Ted: "Judges would have to remember how the people's teeth look because you really couldn't tell unless you had something to compare them with."

Robert: "Even if you had half of the group chew gum, still two peoples' teeth wouldn't be the same, and you would still have trouble."

Dick: "The judges should not know anything about it."

Robert: "Judges might be biased and would not give a good judgment."

Richard: "Let one judge pass out the gum and take all the other judges out of the room."

Teacher: "Do you think Richard and Norman would make the best judges for this? Would Richard and Norman be good to use in John's experiment?"

Ted: "No, because they don't think it is any good to begin with."

Teacher: "Do you, Richard, think you would be a good judge?"

Richard: "No, I would favor the ones without the gum in the first place."

Norman: "I feel the same way."

Teacher: "Why would Norman and Dick favor the people who did not chew gum?"

Group Answer: "Because they don't think gum is any good for the teeth."

Teacher: "Do you think John's experiment is the best?"

Robert: "The experiment would be the best one if the judges were in the next room. There isn't any experiment where the judges don't know who is chewing gum."

Teacher: "Let's look at all experiments to see if any of them have the judges in the next room where they don't know who is chewing gum."

Teacher: "Does everyone know who is chewing gum in Mary's experiment? What about the judges, Ralph, did they know anything about the chewing gum?"

Ralph: "They were out."

Teacher: "Shall we mark Mary's experiment 'yes'?"

Group Answer: "Yes."

Robert: "If the judges guess which had been chewing gum all right, it would prove it was right, but if they guessed some wrong, it would prove the experiment wasn't right."

Teacher: "Would that prove the judges guessed?"

Dick: "The judges are telling the truth."

Laura: "A dentist would make a good judge."

Teacher: "Why, Laura?"

Laura: "He knows about the teeth."

Robert: "The dentist would know the answers."

Teacher: "Would the dentist be a good judge?"

Robert: "The dentist might not like chewing gum and would talk against it."

Teacher: "What is a judge supposed to do in this case?"

Dick: "Just examine them and tell which ones got cleaner or just stayed the same."

Teacher: "What does the judge do?"

Robert: "He examines them again."

Teacher: "What for?"

Robert: "He judges which one has the cleaner teeth."

Smitty: "He finds out which ones have changed the most."

Teacher: "What does he mean by changed the most?"

Group Answer: "The teeth have become cleaner."

Teacher: "How can we get around the idea of just remembering it?"

Robert: "Give him a rating."

Teacher: "How could we find out if our teeth are clean?"

Robert: "If we have a film on them."

Teacher: "How can we find out if our teeth have a film on them?"

Patricia: "If they are yellow."

Teacher: "Tell us why John's experiment would be 'Yes' or 'No'."

Robert: "John's would be 'No', but Mary's 'Yes'."

Teacher: "Why is John's experiment 'No'?"

Robert: "The judges are relying on remembering whether or not the teeth were clean in the beginning."

Teacher: "How would you mark John's experiment?"

Group Answer: "No. The judges could not remember who had the clean teeth."

Smitty: "They could have written them down."

Dick: "Have a chart for each person to see what their teeth are like if they are clean."

Teacher: "Does the color of teeth tell whether or not they are clean?"

Richard: "To an extent."

Teacher: "Does the color tell us or could any teeth be white but still be dirty?"

Joan: "Teeth can be white but still be dirty. Judges should use something besides color."

Teacher: "Does it affect it if they send judges out of the room?"

Norman: "It is the same thing."

Allen: "In Carl's experiment judges did not examine people's teeth before leaving the room."

Teacher: "Does that make a difference? How?"

Donald: "If the judges did not examine the teeth, they don't know whether they were clean or dirty when they started."

Teacher: "Do you think we might give better reasons for our answers if I let you take the test again?"

Group Answer: "Yes."

At this point the instructor passed out a new set of quiz papers, and the pupils recorded their latest thinking before the bell rang.

In planning for the next class session the instructor completed the following preparations:

1. A careful examination of each student's pretest was made to determine whether or not he had been able to select and express any of the seven reasons why the various experiments were inadequate for testing the criterion statement. It was discovered that 12 students had been unable to formulate any correct reasons for the inadequacy of the experiments. Eight students had been able to formulate one correct reason, and two students had been able to formulate two of the reasons. Upon comparing responses to the pre- and end-tests, it was further discovered that there were not only certain distinct gains, but also much repetition of errors, and, in a few instances, individual students actually made poorer responses on the end-test than they did on the pre-test.

2. An overall analysis of the pre- and end-test results identified those areas which would need further clarification and discussion before students were asked to participate in the actual activity of designing and completing purposeful experiments. For example, this analysis indicated that not one student had recognized a glaring weakness in Mary's experiment. They had failed to discriminate between the terms cleanliness and whiteness of teeth. They seemed perfectly willing to accept a measure of whiteness as a test for cleanliness. Furthermore, only three students had gained in ability to identify the lack of controls in John's experiment. On the other hand, a sharp rise was registered throughout the class in the ability to identify the lack of a pre-examination in Carl's experiment. One of the most interesting results of the analysis indicated that several students who had marked on the pre-test that Mary's experiment would not adequately test the criterion statement changed their opinions and made an incorrect response to this item on the final test.

The analysis further revealed the fact that only one or two students in the entire class had recognized such important points as, (1) the bias of judges and how to control it, (2) that the two-hour period for chewing gum was possibly inadequate to test the hypothesis, (3) that a group of 20 might be to small a sample, and (4) that judges should be selected on the basis of competency.

3. On the basis of the above preparation the instructor was able to make specific plans for continuing the discussion in such a way as to bring out specific points which had not been adequately clarified in the previous discussion.

4. Since this particular instructor intentionally planned the discussion so as to emphasize student contributions and to minimize the "teacher-telling" process, it was highly important for him to analyze the actual class discussion in order to organize specific steps for improving his ability to guide future discussions in a manner which would help students arrive at accurate conclusions and reasons. The preceding analysis of the changes in pupil reasoning confronted the instructor with a number of problems:

(1) Why had no student been able to discern the weakness in Mary's experiment? An analysis of the discussion clearly reveals that, although the factor of color was brought into the class discussion at several points, at no time did the instructor pursue the point until its meaning had become clearly identified with Mary's experiment. Furthermore, no student clearly pointed out that whiteness was not necessarily a measure of cleanliness, although Joan came close to it when she said, "Teeth can be white, but still be dirty. The judges should use something besides color."

(2) On the pre-test, four students used, as a reason for marking one or more experiments as inadequate, statements similar to the following: "Judges could not *remember* how the teeth looked at the beginning." This particular reason was con-

sidered inadequate by the instructor since there was nothing in any of the experiments that indicated that the judges had to remember the results of their first examination. Nevertheless, on the end-test 12 students used this type of reasoning. Why this shift to a reason which the instructor considered inadequate? An analysis of the discussion clearly revealed that the teacher attempted to point out through questioning that the judges did not need to rely on remembering whether or not the teeth were clean in the beginning. That he was not successful is indicated by the fact that there seemed to be a group fixation concerning John's experiment when they mimicked Robert's response, "The judges are relying on remembering whether or not the teeth were clean in the beginning." This fixation was not decisively refuted in the ensuing discussion which pointed out that the judges could have written or charted the results of the pre-examination.

This was obviously a weak spot in the discussion since the students were allowed to settle on a reason which the instructor considered inadequate and, in the process, tended to overlook the need for more adequate controls in John's experiment.

(3) Why did several students change their opinions and mark on the end-test that Mary's experiment was adequate for testing the statement? This also was contrary to the desire of the instructor. Again, an analysis of the discussion showed that the instructor allowed the group to focus on the incorrect response when he said, "Shall we mark Mary's experiment 'Yes'?" Immediately, the group responded, "Yes," and the subsequent discussion never quite refuted this fixation.

Summary

The above discussion is an authentic recording of an actual classroom situation in which an instructor was practicing the next step in evaluation: that of making it part of the teaching-learning situation on a daily basis. Far too often teachers think of examinations as necessary evils to be given only at the end of certain time periods and for the specific purpose of assigning grades to students. Some of the salient features brought out in the foregoing discussion are as follows:

1. Testing materials must be given at the beginning, as well as at the end, if the teacher is concerned with *changes in behavior*.
2. Using test materials as a springboard for class discussion helps both the students and the teacher to focus their activities on specific objectives.
3. Having each student spend a short time at the beginning of the class to become personally involved in making written decisions helps to create within each individual a personal challenge to defend those decisions, and thus encourages a large number of students to participate actively in the discussion.
4. The procedure of using informal test materials in the classroom helps the students to become acquainted with the objectives of the course as they will eventually be revealed to them through formal examinations. How often students have complained that failure in a course has been largely due to unfair examinations which were not clearly emphasized in the class work! Any thoughtful college student will tell us that, regardless of what a professor might say are the objectives of a given course, the practical objectives for the student are seldom more clearly revealed than when he takes his first examination in the course. Why not use test items from time to time as a way of introducing new objectives and new units of work in the classroom?
5. Using short quizzes helps to provide a continuous record of individual student achievements, errors, and changes in behavior. These types of materials should not be filed for teacher use only but should find their way back to the individual pupils, placing in their hands irrefutable materials which may form the basis for their personal plan of improvement.
6. An analysis of the quiz results can give the teacher a down-to-earth picture portraying those steps which must be taken in the succeeding class meetings.
7. Tests, properly designed, may enable the teacher to anticipate or predict the relative difficulty of attaining identified objectives.
8. Probably one of the most important outcomes of such evaluation techniques, yet one of the activities least often pursued by teachers, is that of improving the instructor's teaching techniques. This situation was one in which the instructor was devoted to a discussion technique based on active thought by students rather than inactive listening to correct answers as provided so often by the lecture method. The recording of the class discussion, however, clearly revealed that such a technique is most complex and needs careful study if a teacher is to become effective through its use. In this particular situation the instructor planned five specific points for improving future class discussions. They were as follows:

(1) During the discussion carry in hand a list of the specific points which the discussion is expected to clarify.

(2) Carefully select from the students' discussion statements pertinent to the pre-formulated objectives and then persistently pursue them to a decision which is obvious to the majority of students. To accomplish this the teacher must plan definite ways of minimizing irrelevant remarks.

(3) Avoid making statements which bring about pupils' fixation in a manner which substantially reduces individual thought. In general, students are prone to seek clues as to what the teacher thinks is a correct response and, by the same token, avoid critical thinking. An example of a student responding to social pressure was found on Norman's end-test paper when he reversed his response to Mary's experiment. In reversing his response he wrote, "I say 'yes' because everybody else says so, but I still think the answer is 'no'."

(4) When introducing new topics, use a simple quiz which contains only two or three difficult concepts. Scrutiny of the discussion pointed out that the situation involving three experiments was a little too complex for the students to handle when the material was new to them.

(5) Refine the instructional test items by studying the student responses. As an example, student repetition and fixation on the idea that judges would have to remember how clean the teeth were could have been obviated by including in the experiments the idea that the judges recorded the results of their pre-examinations.

Teaching Science With Everyday Materials

KENNETH M. SWEZEY

Science Writer, Brooklyn, New York

(MARCH 1962)

THE NEXT TIME your laboratory assistant disappears or the apparatus specified in your textbook fails to arrive, do not give up in despair. Just commandeer a few simple things around you—tumblers, string, rubber bands, apples from your lunch box, toy balloons, electric fans, or what have you—assemble them with imagination, and carry on! Chances are that the class interest will run higher, and that you will come closer to revealing the essence of an experiment or a demonstration, than if you had used more complicated and expensive traditional materials or equipment.

Many of the greatest scientists of history are remembered largely by such simple and dramatic showmanship. The toy jet-propelled steam engine exhibited by Heron of Alexandria more than 2000 years ago is used today to teach the principle of steam and gas turbines, jet engines, and rocket motors. Merely by dropping weights from the *Leaning Tower of Pisa,* Galileo helped to revolutionize the scientific thought of his day. Michael Faraday's famous lecture-demonstrations on *The Chemical History of a Candle* packed the auditorium of the Royal Institution with school children *during their Christmas holidays.* Now in book form, these are still among the best sellers a hundred years later!

You can go a long way toward making your demonstrations more exciting, easier to do, and less costly, merely by substituting jam jars and tumblers for laboratory cylinders, rubber bands for coil springs, and so on down the line. For outstanding presentations, however, you must rethink completely the science behind them, discard everything that is unnecessary or irrelevant, and then you often emerge with an entirely new technique better suited to the simpler equipment.

From more than twenty-five years of experience in devising and adapting several thousand demonstrations of everyday science—first for the "Home Science" department of the *Popular Science Monthly,* then for general magazines, experiment books, textbooks, teaching films, and television—these criteria seem to me to be the most important:

1. The demonstration should help explain a device or experience in which a student is actively interested, rather than merely an abstract scientific law about which he knows nothing and for which he can yet see no practical use.
2. It should involve the simplest and most familiar equipment possible.
3. Its result should be capable of being observed directly.
4. The result should contain an element of wonder or surprise.
5. The science behind the demonstration should be sound and capable of leading to broader discussion and experimentation.
6. It should be repeatable by the student at home for his own pleasure and edification and, even for that of his family and friends.

Do not expect, however, that *every* experiment—even with the greatest effort—can be adapted to meet *all* these standards. One of the lucky ones that seems to do so was evolved by the writer during World War II, as part of the general effort at that time to improve military and pre-induction science training. All you need to perform it are two apples (oranges, baseballs, tennis balls, or small soda bottles will serve as well) hung at mouth height and about an inch apart on long strings (Figure 1). Blow strongly between them and what happens? "They will fly apart," reasons the science novice. To his surprise, they actually *bump together* (Figure 2). Why? For the same reason that an airplane flies, a baseball curves, and paint and insecticides rise against gravity in spraying devices!

For years this potentially ideal demonstration had slumbered as a mere parlor trick or just another of many manifestations of the little-known-to-the-layman "Bernoulli's principle." The originators, apparently underestimating the considerable force of atmospheric pressure, had invariably used lightweight ping-pong balls and, apparatus-minded, they had gratuitously added a soda straw through which the performer must blow.

By eliminating the straw, substituting more impressive and easily accessible apples and oranges

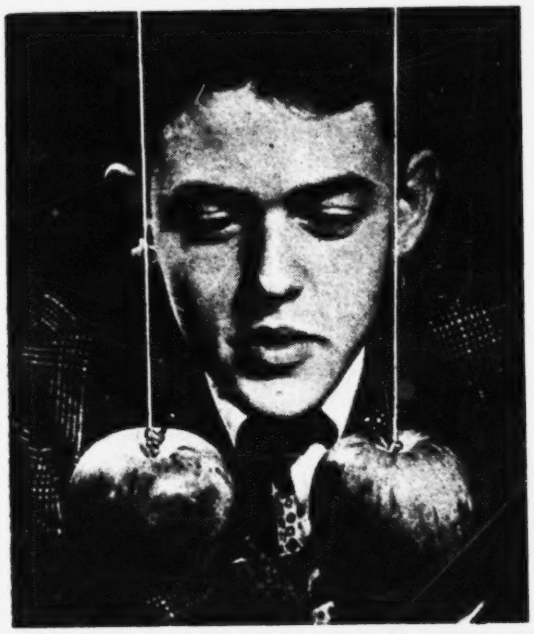


FIGURE 1. The student's breath is blown between two apples which are hung on strings.

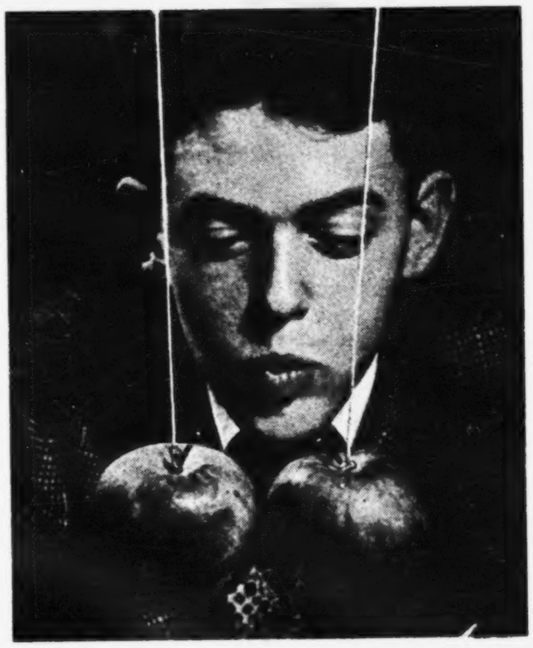


FIGURE 2. The results demonstrate graphically one of the reasons airplanes fly.

for ping-pong balls, and linking the explanation with an extensive discussion of the flight of airplanes, instead of just the abstract underlying principle, the stunt suddenly came to life. Besides appearing in science and aviation magazines, *The Saturday Evening Post* featured it among other simplified demonstrations as "The Parlor Trick That Makes Planes Fly"; it was promoted on two of the pioneer TV science programs, and has since become part of the stock in trade of many other TV programs and experiment books.

Another ideally simple demonstration that illustrates the same principle requires only a toy balloon, a couple of paper clips, and an electric fan. First point the fan upward and turn it on. Then drop the balloon into the air stream. (The balloon should have been weighted before class with enough paper clips, clipped to its neck, to prevent it from being blown too far away from the fan.) Although the balloon bobs up and down, it cannot leave the stream because of the envelope of high-speed low-pressure air flowing around it. Every time it reaches the edge of the stream, the quiet, higher pressure air of the atmosphere pushes it back.

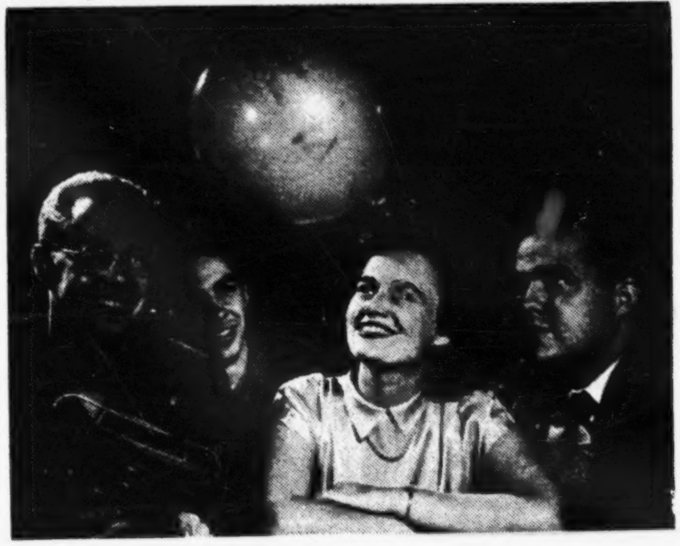
To create an even more mystifying effect, tilt the fan as shown in Figure 3. Seemingly disobeying the laws of gravity, the balloon still stays in the stream —falling out only if the fan is tilted so low that the pull of gravity becomes stronger than the upward pressure of the atmosphere.

Many of the classic experiments, described in textbooks for generations almost unchanged, can be performed more interestingly and instructively with less complex everyday items.

The mysterious "Bottle Imp," or "Cartesian Diver," devised over three hundred years ago as a toy to amaze the layman, is an example. In its original form (still shown in textbooks) it consists of a small blown-glass man or demon, having a tiny hole in its leg or tail, which floats in a cylinder of water covered by a flexible diaphragm. Press or release the diaphragm (forcing more water into the man, or letting it out) and the man dives or rises.

For mere mystification, the original design is still fine. For demonstrating the compressibility of air and the incompressibility of water (for which purpose the diver is usually included in textbooks), however, you can do better with everyday materials that show precisely what is happening. One combination requires only a bottle of water, a medicine dropper, and a cork (Figure 4). Fill the dropper from a tumbler of water until it just barely floats, put it into the bottle, filled to the brim, and insert the cork. If the amount of water in the dropper is right, slight pressure on the cork will now cause your "diver" to sink; slight loosening of the cork will cause it to rise. At first as mysterious as the traditional "imp," close observation of the water level in the dropper will enable a student to deduce for himself the principle behind its action.

FIGURE 3. Why does the balloon stay in the air stream? Simple, thought-provoking experiments like these help stimulate inquiries into many broad fields of science.



A thought-provoking experiment involving inertia, requiring traditionally "a heavy metal ball, suspended by a light thread just strong enough to support it," can be done more conveniently and less dangerously (What would happen if the ball should fall on the performer's wrist or toe?) by suspending a moderately-heavy book by a light string and tying a similar string below it, as shown in Figure 5. The question you pose to the class is how one can break either string at will, merely by pulling on the bottom one? The student who understands the law of inertia will give a quick jerk to break the lower string, and pull steadily on it to break the upper (thus adding the force of his pull to the weight of the book).

To demonstrate the always-astonishing phenomenon of *regelation*, do not think you need the huge cake of ice (supported by sawhorses, tables, boxes, chairs, and straddled by a wire hung with "brass" weights!) indicated perennially in textbooks. You can get the same result—much faster, with more fun, and far more conveniently—with an ice cube from the lunchroom refrigerator. (Examine Figure 6.) Provide handles at the ends of an eight-inch length of thin, strong wire by twisting each end around the middle of a large nail or a pencil. Place the ice cube (which should not be too much below melting temperature) on top of a soda bottle, upended stick, or other convenient support. Then straddle the cube with the wire and bear down as hard as you can on the pencils. Within several minutes the wire will cut its way completely through the cube, which, however, will still be whole!

That electricity surrounds us everywhere may better be demonstrated with familiar things than with complicated apparatus. The fact is that every time you lift anything from anything else, or move something against something else, you conjure up a charge of static electricity.

In summer, when most surfaces are moist, this static leaks off so fast it is not even noticed. On a dry winter day, however, you meet it in snaps, sparks, and in objects clinging to or repelling each other. One of the simplest and most graphic ways to show its presence is with a giant electroscope you can improvise in a second. Just tear two long strips from a sheet of newspaper, hold them together at one end, and give them several light downward strokes between the thumb and forefinger of your free hand. The strips fly apart! (Figure 7.) Charged similarly by contact with your fingers, they repel each other.

When your text suggests the use of a neon wand to demonstrate effects of static, an ordinary fluorescent lamp (good or burned-out) will generally do as well. Merely stroke one briskly on your sleeve in a dark room—or, better still, hold one near a long-playing record that has been so stroked—and it will light brilliantly! (Figure 8.)

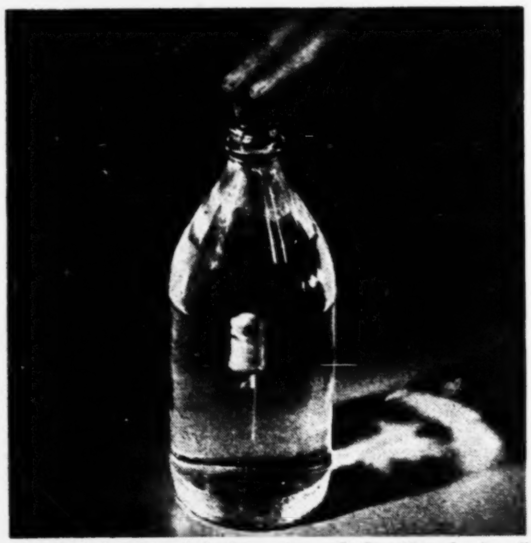


FIGURE 4. Simplified version of the "Bottle Imp" has considerable teaching value because its operation is visible.

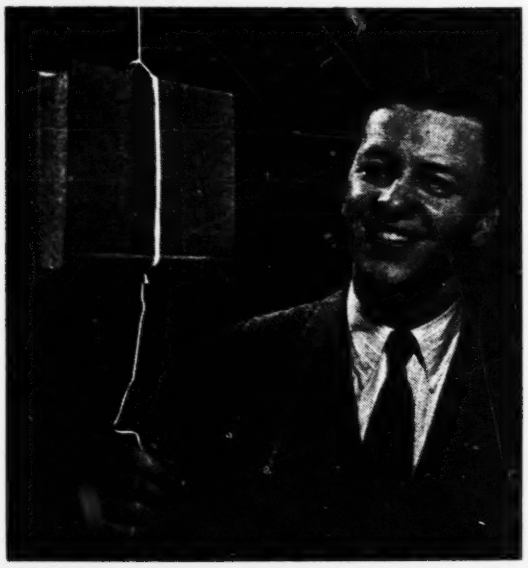
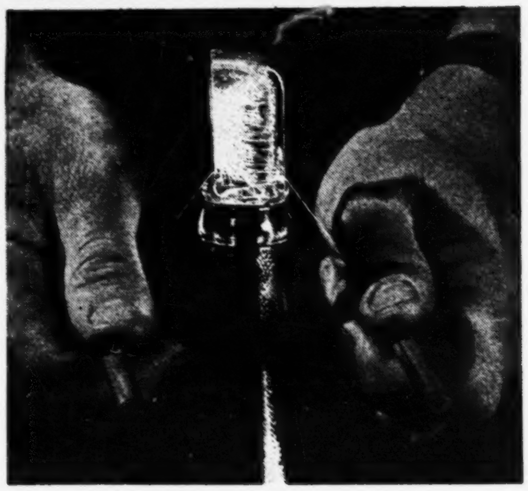


FIGURE 5. Can you break either cord by pulling the lower one? It is possible, if you know the principle of inertia!

FIGURE 6. If the traditional regelation experiment seems too difficult to demonstrate, try this simplified version with an ice cube.



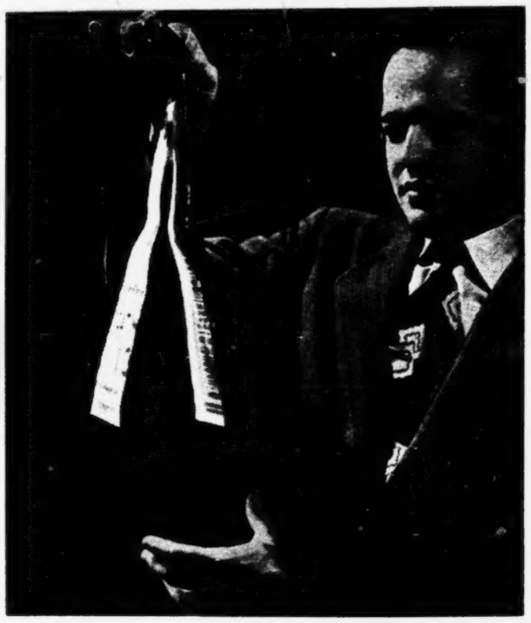


FIGURE 7. An impromptu electroscope made of two strips of newspaper usually dramatizes the existence of static electricity more effectively than a complex instrument.

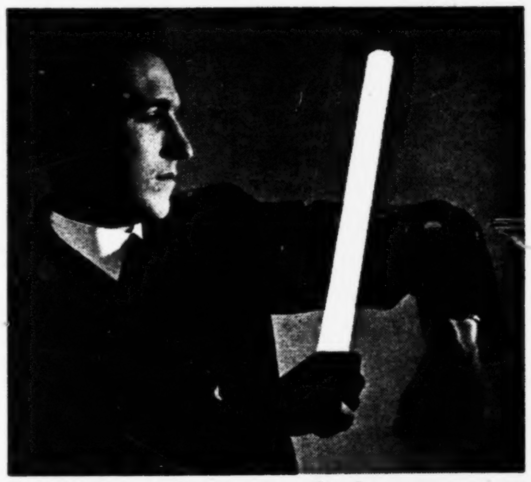


FIGURE 8. A fluorescent tube becomes a neon wand by the friction created through rubbing.

The working of complex devices may often be demonstrated vividly with simple things by seeking the key principle of the device and demonstrating that. You can not take your students inside the mechanism of an electric refrigerator, for instance, but you *can show* how the expansion of Freon 12 (the liquid used in most home refrigerators) can actually produce ice. All the apparatus you need is a metal or glass tube, about one-fourth inch in diameter and four or five inches long, a spring clothespin, or a loop of paper to hold it (to keep from warming the tube or freezing your fingers), and a can of pressurized air deodorant. To demonstrate, merely wet the outside of the tube with water and direct the Freon-propelled jet from the can through it. In a few seconds, the water will freeze to ice (Figure 9).

With a stunt that seems almost like magic, you can similarly demonstrate *persistence of vision,* a phenomenon of sight that makes possible movies and television. If you perform it before a program of slides or movies, the only extra equipment required will be a two-foot length of heavy white cord (venetian blind cord is excellent) with a small weight tied to one end. With the room dark and the projector turned on, merely hold this cord by its free end and whirl it rapidly in a plane parallel with the face of the projector lens. (For best effect, focus the projector secretly on your whirling string and whirl the string later in the same spot; do not make the picture too large and keep it well out in the room so the image on the distant wall will be dim and out of focus.) A picture appears in mid-air (Figure 10) on nothing but a moving piece of string!

FIGURE 9. A simple demonstration of cooling by expansion of Freon-12 results in a quick freezing reaction. No complex devices are needed.

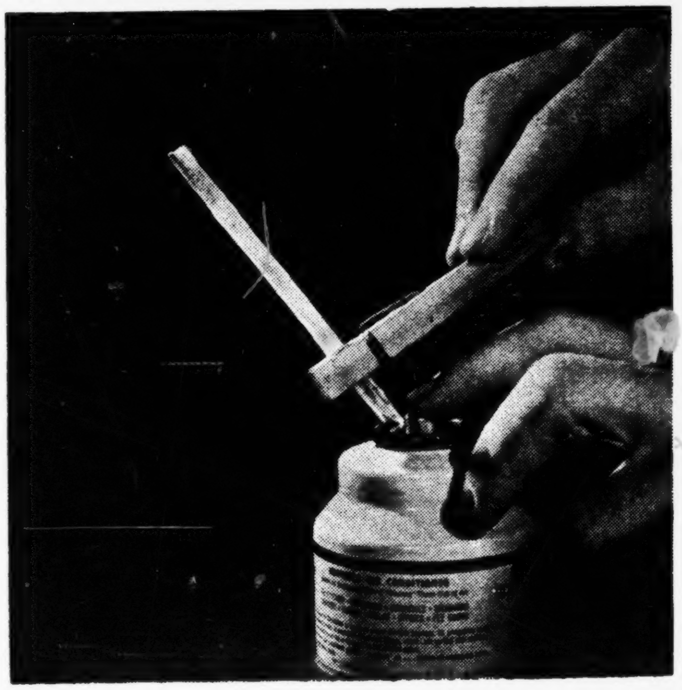
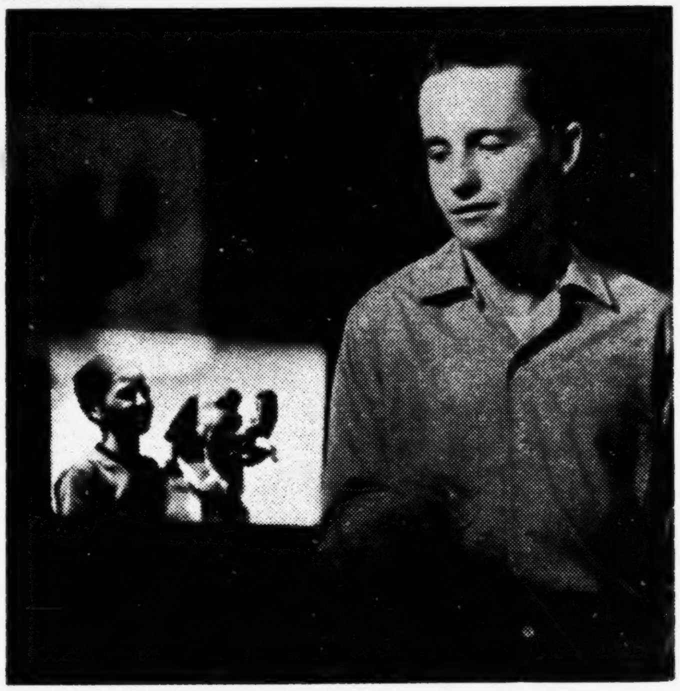


FIGURE 10. Projected image on whirling string demonstrates one of the principles which enables us to have movies and television.



The Community as a Basis for a Unit on Water

GLEN A. GEISERT

Chairman, Science Department, East High School, Pueblo, Colorado

(FEBRUARY 1952)

The teaching of general science in the past has been merely the presentation of a group of facts or principles not particularly related to anything, least of all to the pupil and his environment. Trends in science education today demand that the science teacher be concerned with the pupil and his community. Teaching becomes effective when it is rooted in the needs and problems of the people in the community and its schools.[1]

In order for the teacher to be able to incorporate the community into the subject that he is teaching, he must know the community. This can be done only by extensive research on the part of the teacher or a teacher-pupil combination. In basing a unit on the community it is necessary for the teacher to do two things to be successful: (1) become a part of the community, and (2) be able to focus on community problems.[2] If the teacher can do these two things, he then can start building the course of study for the subject which he is teaching, using the community as a basis.

Four Steps in Developing the Unit

Without the community as a basis for a unit of work, it will be found difficult in many instances to stimulate the pupil in various units of general science. If the pupil can see no relationship between himself or his community and the subject he is taking, it means little or nothing to him. The first way in which the pupil can be made to realize that the unit is important to him is to include the pupil and/or his community in the statement of the main problem used for the unit. Since few textbooks have the main topics in the form of a problem, it is necessary for the teacher to restate the topic in problem form.

Getting away from the traditional type of introductions is the second thing that a teacher can do to stimulate the pupil interest in the unit. The introduction should be conducted in such a manner that problems will arise from the experience. Three methods of introducing units which have been found effective are: (1) using a bulletin board display of pictures under which are placed questions related to material contained in the unit; (2) using a newspaper article of a situation existing in the community that can serve as a foundation for a unit; and (3) using historical and legendary stories about material in the unit showing how attitudes have changed as a result of scientific advancement.

The third tool which the teacher can use is the study guide. The community would be the central theme of the guide. Some subject matter questions should be included in the guide to help the student see the relationship between the community and subject matter. All of the study guide questions should be thoroughly discussed. The amount of material that the teacher would want to grade would depend upon the individual teacher.

The use of desirable activities is the fourth way of stimulating the pupil. The activities include experiments using materials with which the student is familiar and which are common to the community, field trips into the community, and special reports about related problems in the community.

To show how these four steps can be carried out, the general science unit on water has been chosen as an example. Only one method of introduction will be used, that being the bulletin board method. A complete study guide could not be given due to lack of space, and as a result only two of the minor problems will be developed.

1. Restatement of the Topic

The original topic as it might appear in a general science textbook is "Water and Its Uses." The restated topic in problem form might be as follows: Why is water important to me and the community in which I live? This main problem can be subdivided into as many minor problems as the teacher desires. A suggested list of seven minor problems is as follows:

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[1] Laton, Anita D., and Meder, Elsa Marie. "Toward Unified Learning," *Teachers College Record*, January, 1944, pp. 225.

[2] Evans, Hubert M. "The Teacher of Science and His Community," *Teachers College Record*, January, 1944, pp. 253.

1. What is water and where is it found in my community?
2. What are the important properties of water? What effect do these properties have on me and my community?
3. What effect does running water have on my community?
4. What are the sources of our community water supply?
5. What is the manner of distribution to my home?
6. How is our city water supply purified?
7. How does our community dispose of the sewage?

By using the word community rather than city in most of the problems, the rural areas as well as the urban areas are included.

2. Introducing the Unit

The introduction of the unit on water can be effectively accomplished by the use of a bulletin board display of a group of pictures that are in some way related to the community and water. The interest in these pictures can be aroused by the placing of pertinent questions under the pictures. Ask the pupils to answer the questions. It is not expected that the pupils can *answer* all of the questions, but they should *attempt* all of the questions.

A suggested list of pictures and questions appears below.

1. A snow covered mountain with a lake in the foreground with ice on the lake. In how many states is water existing in this picture? How many possible sources of water do you observe in this picture?
2. A large dam from nearby. What property of water makes it necessary to build the dam so thick at the bottom?
3. Fish jumping out of water. What property of water makes it possible for fish to survive in the watery environment?
4. Drouth in the southwestern regions of the U. S. What region of the United States suffered a crippling drouth during the summer of 1951?

This is only a limited number of the many types of pictures that might be employed to introduce this unit. Actual photographs from your own community could be used very effectively.

After the pictures have been displayed and the questions answered, the pupils should be asked to write down a list of questions that *they* have about water. After the group of questions has been completed, ask them to check the one that they feel is of the most importance to them in their daily life. Through this activity, the teacher has created problems that can be solved during the course of the unit. The teacher is then familiar with problems that the pupils have in relation to this unit.

3. Study Guide and Activities

In this sample of the study guide the emphasis has been placed on the individual and his community in relation to water. The reading material to accompany the guide will have to be worked out by the individual teacher since the same textbook is not used by all of the schools. Therefore, the directions for the use of the guide have been intentionally omitted. Activities that might be used with these two minor problems have been suggested.

MINOR PROBLEM: WHAT IS THE MANNER OF DISTRIBUTION TO MY HOME?

1. If you live in a rural area, how is water distributed to your home?
2. List other possible methods of distribution to rural homes.
3. Check the method that you think is the best. Why do you think that it is the best method?
4. What are the methods of supplying water to cities?
5. How is water stored in this city?
6. How is the water distributed to the residents of this city?
7. What is the method used to provide the necessary pressure for the water system?
8. How many gallons of water are used per day in this city?
9. What is the average daily consumption per person?
10. How do the residents of this city pay for water that is used?
11. What are the advantages and disadvantages of this plan?
12. What problems might this city face in the future in respect to water distribution?
13. How might these problems be solved?
14. What are the uses of water in this area?
15. Check the uses of water that could be eliminated if it became absolutely necessary to do so.

MINOR PROBLEM: HOW IS OUR CITY WATER SUPPLY PURIFIED?

1. What are the requirements for pure drinking water?
2. Do we have pure drinking water according to these requirements? Why?
3. What methods of purification of water supply are used in the rural areas surrounding this city? Why?
4. How is it ensured that the rural supply is pure?

5. What methods of purification are used by cities?
6. Which of these methods of purification are used in this city?
7. How many gallons a day are purified? How much germicide is used for this amount of water?
8. How could our water supply become contaminated?
9. Which of these ways of contamination is the worst?
10. How is the water supply in this city tested for contamination?
11. How often is the water supply tested?
12. What are the minimum requirements for safe drinking water as set up by the state health department?
13. What are the possible results of having an impure water supply?

ACTIVITIES

1. Visit the city storage and water purification facilities.
2. Ask a member of the city water department to talk to the class about local water problems.
3. Conduct simple demonstrations to illustrate the different methods of water purification.

Summary

Many teachers of science believe that it is impossible to integrate the community into the subjects which they are teaching. Other teachers feel that it is too time-consuming to try to develop a subject on the basis of the community. Any new method that is tried will seem to have these two disadvantages. The integration, if tried, will be neither difficult nor time-consuming. It is admitted that more time will be required than that used in developing the traditional textbook method. If the time is given to the development of a general science course with the community as a basis, the teacher will have the satisfaction of having given the pupils a course that is not only more meaningful but more interesting.

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Literature as Science Experience

ZACHARIAH SUBARSKY

Chairman, Biological Sciences Department, The Bronx High School of Science, New York City

(FEBRUARY 1952)

The science teacher who is given the responsibility of teaching bright, science-minded students is challenged to provide for such students educational experiences in science calculated to develop depth of understanding and appreciation. The teacher provides such an experience when he leads the student to understand and appreciate a classical scientific paper such as Gregor Mendel's *Experiments in Plant Hybridization.* (Copies of this paper, originally in German, are available in English translation from the Harvard University Press.)

Merely to give the paper to a student to read is futile: in the first place, the language is too difficult even for the very bright student; in the second place, the student lacks the background of experience and information needed to understand the text; in the third place, the broad significance of the investigations described in the paper are not readily apparent to the student. To overcome these difficulties, a teaching procedure has been worked out at the High School of Science, a procedure designed to lead the student to an understanding and appreciation of part of Mendel's paper.

1. Providing the framework for the study of Mendel's paper. The unit on heredity is introduced. The variety of possible approaches and meaningful motivation devices for introducing this unit are well known to the experienced biology teacher. The introduction generally includes heredity problems raised by the students themselves—problems such as:

> Are the children of bright parents all born bright?
> If my parents die of heart disease, will I die of heart disease?
> Is being overweight hereditary?

The teacher elicits or states the fact that there is a branch of biology devoted to an investigation of such problems and then asks: "Who was one of the pioneers in this branch of biology?" In a bright class some student is sure to come forth with the name of Mendel—it has never failed. The teacher then elicits or states the fact that Mendel's discoveries were made in experiments with pea plants, and since Mendel's discoveries have shed light on such problems of heredity as were raised by the class, these experiments are worthy of study. But what better way is there to find out about Mendel's experiments than to let Mendel himself tell what he did and saw! At this point a copy of the paper is shown and the date and circumstances of its delivery are noted. The class is informed that since Mendel experimented with pea plants an acquaintance with the pea plant and a thorough knowledge of how the pea plant reproduces is essential to an understanding of Mendel's paper.

2. Providing the background of information and experience. Several laboratory lessons are then devoted to the study of the reproduction of the pea plant, quite in the conventional manner, but with this modification: that throughout these studies the points of information essential to an understanding of Mendel's paper are emphasized. For example, the terms "keel," "seed coat," and "albumen" are used. The "surgical operation" involved in cross pollination is demonstrated. In studying the fruit and seeds, inflated pods and constricted pods are shown (corresponding varieties of string beans obtainable in the vegetable market will do), green seeds and yellow seeds are shown (green and yellow split peas will do), wrinkled and round seeds are shown (these are obtainable in most grocery stores as dried whole peas). Charts showing terminal and axial inflorescence are shown. Moreover, throughout the study, the name of Mendel is brought in again and again. For example, in showing yellow seeds, the teacher says, "One of the kinds of pea plants Mendel worked with produced yellow seeds like these." The frequent reference to Mendel during the study of floral reproduction serves to keep the purpose of the laboratory work in mind.

Class Studies Idea Development

3. Helping the student to understand and appreciate the paper. When the class is ready, copies of Mendel's paper are distributed. The class is asked to imagine itself the members of the Naturvissenschafts Verein in Brunn in the year 1865. One of the students is asked to play the part of Gregor Mendel reading his report. The student reads the first paragraph. (The teacher will find it necessary to explain unfamiliar words like "progeny.") The teacher then raises the question: "Where did Mendel get the idea for his experiments?" This question is designed to stimulate the students to give in their own words the meaning of the paragraph just read. It also gives the teacher the opportunity to lead the class to see that a scientist does not decide to conduct an experiment "out of the blue." Experimentation is the outgrowth of puzzling experience.

The reader (or another reader) then reads the second paragraph after which the teacher takes time out to elicit and emphasize the fact that there was an international group of forerunners of Mendel who "have devoted a part of their lives with inexhaustible perseverence" (words are those of Mendel) to problems of hybridization Emphasis is placed on the fact that a good scientist first finds out what investigations *others* have made on a problem to be investigated.

The reader (or a third reader) then reads the remaining paragraph of the "Introductory Remarks." The students learn that the report covers experimentation that took *eight* years to complete —twice the students' entire high school career! Here, the teacher takes time out to emphasize the point that one of the traits of a good scientist is patience and perseverence.

The class then goes on to learn, directly from the paper, why Mendel selected the pea plant for his experimentation. The teacher takes time out to emphasize that the wise choice of an experimental plant or animal is an important factor in the success of a biological experiment.

The class then goes on to learn about the varieties of pea plants selected and tested for experimentation and to learn about Mendel's set-up of a series of seven replicative experiments. Here the teacher has the opportunity to point up the "beauty" of experimental design and the ingenuity involved in anticipating extraneous factors that might ultimately obscure the results of an experiment.

The class then reads Mendel's descriptions of the F_1 generation in the series of seven experiments. Here the teacher has the opportunity to lead the class to appreciate how keen and discriminative are the observations of a first rate scientist.

The figures for the F_2 generation are then written on the blackboard and the class left to *discover* for itself the 3:1 ratio. The class is then challenged to give an *explanation.* The class, usually stumped, is ready to appreciate yet another element in scientific genius—the ability to formulate hypotheses to explain the results obtained in experimentation.

Hypotheses Explained and Applied

At this point Mendel's paper is set aside and Mendel's hypotheses are presented by the teacher, namely (1) that each plant inherits *two* factors for each trait, and (2) that the two factors of each pair separate when gametes are formed. An understanding of how these two hypotheses serve to explain the 3:1 ratio is hammered home through the usual "chance" exercises—tossing of coins, blind selection of marbles, etc.

The class, now ready to observe and explain simple monohybrid inheritance in other organisms, is well along in its study of the unit on heredity.

We are now attempting to develop an effective teaching procedure for utilizing William Harvey's classical work in *The Motion of the Heart and Blood,* published in English Translation (from the Latin) by Henry Regney Company, Chicago, Illinois. It is conceivable that teaching procedures could be worked out for other classical papers in the literature, not only of biology, but of other sciences as well. A classical paper thoughtfully presented can be an enriching experience in science for all students.

Display Areas and the Group Technique

THEODORE W. MUNCH

Professor of Science Education, Arizona State University, Tempe, Arizona

(NOVEMBER 1956)

TIME is the teacher's villain when plans are considered for displays of pictures and objects in the classroom. Few teachers would question that visual aids help immeasurably in making science subject matter more meaningful to students. In a teacher's busy day, however, there is little time for the frequent assembling of displays. The solution to the time problem can well be use of the group technique.

The teacher can have the entire class take part in the construction of display areas by selecting small committees to present their work to the class throughout the year. When such a plan is incorporated into the curriculum, the successful completion of the display area calls for careful teacher planning and supervision.

The following suggestions have been gleaned from experiments conducted with two classes of biology and one class of personal hygiene in the 13th grade of Fullerton Junior College, Fullerton, California. Approximately 120 students were involved in the experiment, and many of the ideas which follow were drawn from answers to a questionnaire filled out by each student following the completion of his display area. The technique described can be used for children of almost any age.

The phrase "display area" is preferable to "bulletin board," since bulletin boards are usually in two dimensions, while display areas have the third dimension of depth. Display areas may consist not only of the usual bulletin board background, but also of objects and/or specimens related to the bulletin board material and arranged in front of or around it.

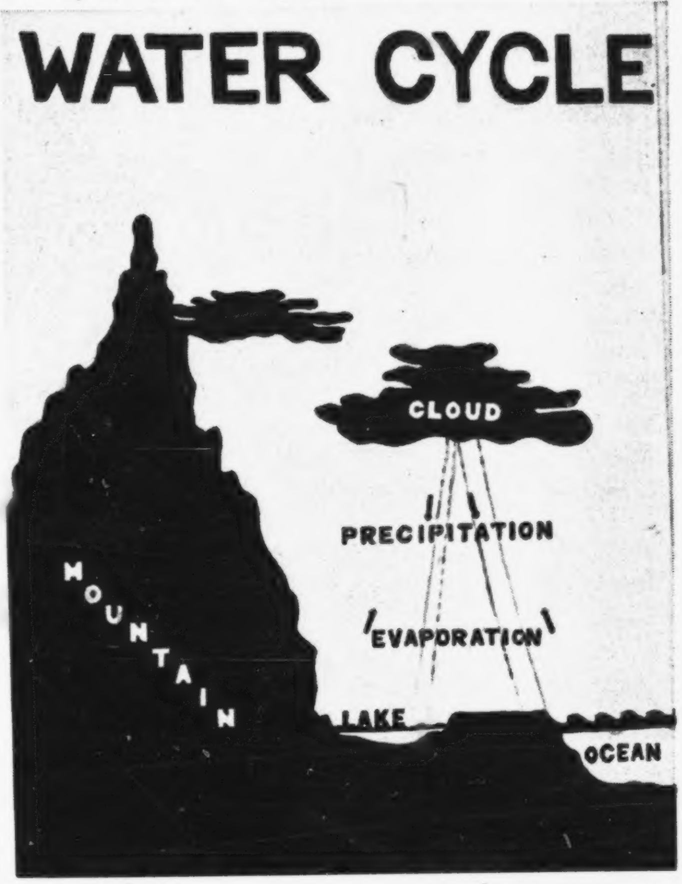
Grouping of Students in Committees

Planning for the display areas should begin early in the semester, preferably following the first week or two after the students have had a chance to grasp, in a general way, the nature of the year's work.

The instructor should make an inventory of the interests and talents of class members by asking them to list problems or questions which are of particular interest or concern to them. The teacher can suggest problems and areas of interest which former students found appealing. The students should have several days to consider their choices, during which time they can discuss their interests among themselves and with the teacher. Each student should make three choices of subject matter areas, listing his choices in the order of their importance to him.

The teacher now chooses the committees, grouping the students on the basis of first choices until the optimum size of the committee has been reached. The committee number which the students termed "just right" was four. With a greater number, there is difficulty getting the members together at one time for planning sessions. Also, the less "vocal" students tend to become members of an "out group," while most of the ideas and information are contributed by the more aggressive students. On the other hand, committees of fewer than four tend to be restricted in ideas.

This and the illustration on the opposite page are photogra by Dr. Munch of displays constructed in his classes.



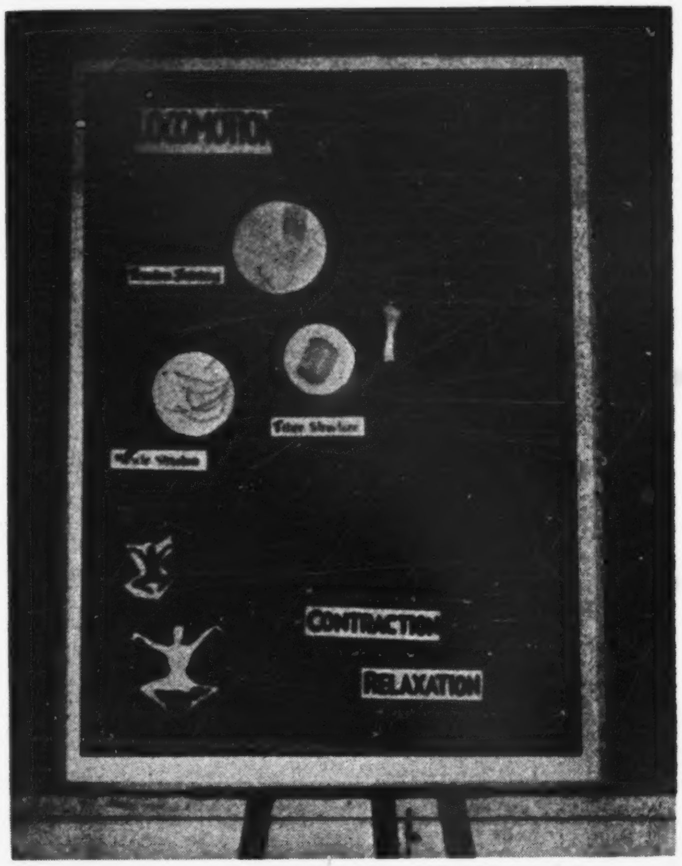
Teacher Planning Prior to Student Committee Meetings

The following general suggestions by the teacher to the class before student committee work begins have been found helpful for a good beginning.

a. Select a coordinator or director for your committee. The coordinator is not to do all the work, nor is he to be held responsible for the success or failure of the display area. His job is to help see that there is no duplication of research, material, or labor.
b. When your committee first meets, decide how much of the topic chosen will make an adequate presentation on the display area. Remember you are limited in space; the ideas presented will have to be concise.
c. Once you have decided on a topic for display, read as much as possible about it. You may want to confer with people in the community in a profession or in industry. As you gather information, make notes for future meetings on small cards or in your notebook.
d. When your committee next meets, discuss or read what you have found in your research and come to an agreement on the important points for the display.
e. In succeeding meetings, each committee member should make a sketch showing how he would like to see the important points of the display presented.
f. When the committee is in agreement on the design of the display, proceed to the problem of securing materials.
g. When all your materials are assembled, the final step is to erect your display and present your material to the class.
h. Evaluation of the display area should be based on the following points. (These may be arrived at by class discussion, but the teacher should be responsible for the weight given to each area of the evaluation.)
    (1) Importance of the scientific ideas presented
    (2) Accuracy of the material
    (3) Originality of the display area
    (4) Form or "mechanics" of the display

Teacher-Pupil Planning Prior to the Presentation of the Display

To insure that the students get well organized, the teacher should attend the first one or two committee planning sessions. A common pitfall to avoid is the choice of a topic too broad for display presentation. The teacher should also make sure that all members of the committee have an approximately equal role in the planning and execution of the project. During these early sessions, the instructor can help the students gain insight into the "give and take" of successful group work. He should point out specifically that groups such as these form the "backbone" of much of our democratic life, and that learning to work with others is a valuable skill in all areas of living. The instructor should feel free to suggest general references for information. If the committee is solving its problems satisfactorily, no attempt should be made to interfere, even if the project is not being planned as the teacher had conceived it.



Follow-up by the Instructor

Periodic checks should be made by the instructor; i.e., asking individuals what information they have discovered, what ideas they have for presentation, and if everyone is contributing equally.

When display areas are made a part of the curriculum, class time should be allowed for some of the planning and work sessions, possibly during supervised study periods. The students should know, however, that some outside time and effort (call it homework) will probably be necessary.

The students may need considerable assistance in procuring simple supplies such as tacks, pins, and tools (stapler, ruler, scissors). A materials center, consisting of a cabinet in which supplies are stored and a table where the students can work, is essential to the easy preparation of display areas. When each display is dismantled, students should return to the materials center all reusable supplies.

Presentation of the Display Area

The presentation of the display should be timed to coincide as much as possible with the planned lesson. This procedure necessitates a rather flexible schedule. Each committee should be notified several days in advance of the day of presentation.

Class time should be set aside during which the committee (or selected members) presents the display to the class and answers questions concerning the science principles behind the display. The teacher should be ready to amplify as much as is necessary and to preside over a friendly critique by other members of the class. The importance of good teacher direction at this point in the presentation cannot be overemphasized. Display areas can and should represent important highlights of a science topic. The display may be used as a skeleton about which to drape many interesting or vital facts concerning class work developed in the immediate past or to be studied in the immediate future. The instructor should integrate with the display as many points and interesting details as possible in order to fully justify the use of class time for this type of presentation. The time spent in hearing how other students react to the display is especially valuable for those still planning displays.

Student Reactions to the Use of Display Areas as a Group Technique

a. The students revealed that many sources were used to obtain facts for the display areas. The textbook and other committee members were the two most important sources. Magazines and pamphlets from the library were also found to be valuable sources. Many students consulted members of civilian agencies outside the school.

b. About half the students reported that not all committee members worked equally in preparing the display. The reasons given were that some members had to work and could not be present at all planning sessions (this could be avoided by allotting sufficient class time for this work) and some of the committees were too large.

c. A majority of the students agreed they would prefer not to work by themselves. Some of the reasons given were: they needed to learn to work together; one person rarely had a sufficient number of good ideas; and it would have been impossible to gather sufficient data alone. Some students would have preferred working alone because: they did not agree with the ideas expressed in the finished display; they would not have had to worry about others shirking their responsibilities; some committees were too large; meeting times were too hard to arrange; and some considered it unfair to evaluate a group on a project to which all did not contribute equally.

d. Only a few students relied on present knowledge from which to draw ideas. The majority agreed that they learned new facts during the preparation of the display, mainly because they had to seek out non-text sources.

e. A majority of the students felt that this type of group project should be used again in other classes. Among their reasons were that this technique: aids in better understanding of the problem involved; enables certain members of the class to express themselves more easily; is superior to the lecture method in presenting facts; and is interesting and fun.

f. The individual committee members spent as much as eight hours and as little as one-half hour in pre-planning discussions. The average was about two hours. Individual research for facts and ideas of presentation demanded as little as one-half hour and as much as 16 hours. Erecting the display consumed as much as 11 hours per individual but the average was between one and three.

g. The cost of the display ranged from nothing to slightly above $1 per individual. The average cost per member was 50¢.

The use of display areas as a group technique can be made successful only if certain things are true. The teacher must be philosophically disposed to believe that education, even in the areas of science, consists of learning more than just facts, principles, and concepts, and that the display area technique is one way of helping students achieve successful inter-personal relationships. The teacher must be able and willing to spend the time necessary to see that the committees get organized and keep progressing. Finally, he must be ready to accept the fact that some part of the course of study must be set aside if ample time is to be allowed for the development of adequate display areas.

Effective Arrangement of Displays

VERA W. TROESTER

Science Teacher, Walter Reed Junior High School, North Hollywood, California

(FEBRUARY 1952)

In business sales records show that sales have been greatly increased when merchandise has been well displayed. Perhaps a few suggestions and techniques in science room arrangement might be helpful in "selling" science to youngsters.

We might ask ourselves:

- In what ways should the science room as a physical setting achieve aesthetic values?
  - Positive Factors:
    - Cheerful, pleasant, interesting and functional
    - Sometimes a science room is interesting, but it is unorganized and cluttered
    - Backgrounds in neutral colors or colors in harmony with the display
    - Plants, cages, etc., must be given enough room to relieve clutter
  - Negative Factors:
    - Too many specimens displayed at one time
    - Background may overshadow display
    - Specimens in all sizes and shapes of containers
- What qualities should characterize a well arranged science room?
  - Pointed use of materials
  - Orderly arrangement
  - Simple displays
  - Change exhibits and displays once in a while
    - Introduce new and special exhibits
    - Arrangement of a special exhibit as a means of arousing interest in some topic which would have made a mere routine lesson
- What part can pupils take in room arrangement?
  - Pupils assist in planning, care of tackboards, and exhibits
  - Display work not always arranged by same group
  - *All* pupils should be encouraged to help in preparation and "setting up" of displays

Some suggestions to follow in setting up a pleasing room are:

- Plan exhibit
- Make simple diagrams of plans on paper
- Study good examples of displays in modern stores
- Analyze, as to design, colored pictures from *Fortune* and other good periodicals
- Blackboards and chalk boards occupy a very prominent space in any classroom.
- Displays in other parts of the room will be improved if they are kept clean when not in use
- Spaces above blackboards should not have pictures strung out in single file, but should be well grouped

Lettering for tackboards or bulletin boards and display cases:

- Simple block letters are best
  - Timely and good in design
  - Easily read
- Letters may be cut from light pasteboard or colored construction paper, using a pattern
- Purchased letters: Plaster or pasteboard
- Cut-out letters can be saved in envelopes to be used again
- Titles should be centered
  - Lay out letters of title on plan
  - Count letters and spaces
  - Measure space where title is to be placed
  - Find middle of space and start at this point to pin letters from center out
  - To get a 3-dimensional effect, letters may be pasted on celluloid or plastic. Effective when used in glass cases

Materials for Tackboards:

- Organization—divided into three divisions
  - Current science
  - Unit of science being taught
  - Division for general school matters

Arrangement of Materials on Board:

- Materials arranged as a unit
- Have pictures and clippings even at the top
- Pictures and pupils' work mounted on neutral

- mats or mats harmonizing with color in picture
- In mounting pictures, entire back surface of picture covered with paste
- Place picture on mat and smooth from center out to remove air bubbles
- Picture may be centered on the mat, or with top and side margins of equal width, and the bottom margin wider than the others
- Materials should be arranged with regard for structural lines of bulletin board
- Materials should be *pinned* at corners, not thumb-tacked

Room displays in cupboards and on side tables:

- Each unit grouped in an orderly manner such as:
- animals in one group, plants in another, etc.
- Do not display too many specimens in one group.
- A balanced aquarium is large enough to be a unit in itself

Design applied to display:

- A simple abstract design in background helps the student to an awareness of the realistic
- *Abstract* means basic—as showing way a tree grows
- Diagrammatic background, such as stylized volcano back of a rock display lends interest
- In placing the display it helps to remember that you always have something satisfying if you follow the pattern of a simple triangle
- Caution—restraint! too many things in a display—very confusing

If You Can't Buy It Wholesale

JAMES B. DAVIS

Administrative Assistant to the Superintendent, Lower Merion School District, Ardmore, Pennsylvania

(APRIL 1952)

This is a report of a joint project carried on at Lower Merion High School. A domestic science class cooperated with a general science class in the study of foods. The project could find a place in almost any junior or senior high school.

The problem of economic purchasing of food arose while the unit on foods was being studied by the general science class. Upon invitation the domestic science class agreed to help on the project.

The common food products were purchased in two different quantities. These were weighed, measured, and counted by the pupils, and the following chart was drawn up. It is to be observed that the ten different food products are all easily stored and are not perishable.

The youngsters were delighted with their results, had the chart mimeographed, and each took a copy home. So—if dad could not get it wholesale, he at least found out how to tell mom to buy it cheaper!

Item	Small Pkg.	Cost*	Large Pkg.	Cost	Money Saved	Amount Gained
Flour	2 lbs.	$.25	10 lbs.	$1.03	$.22	Almost 2 lbs.
Tea	16 bags	.19	48 bags	.49	.08	Almost 8 bags
Oatmeal	1 lb.	.17	3 lbs.	.37	.14	Almost 1 lb.
Velveeta	½ lb.	.35	1 lb.	.59	.11	Almost 3 oz.
V-8	12 oz.	.13	46 oz.	.39	.11	Almost 12 oz.
Mayonnaise	½ pt.	.26	1 pt.	.45	.07	¼ cup
Vinegar	1 pt.	.13	1 qt.	.20	.06	½ pt.
Vanilla	1 oz.	.15	4 oz.	.49	.11	Over ½ oz.
Shortening	1 lb.	.35	3 lbs.	.99	.06	Approx. [illegible] oz.
Peaches (sliced)	1 lb. 1 oz. (2 cups)	.22	1 lb. 13 oz. (3½ cups)	.34	.05	Approx. ½ cup
TOTALS on 10 items		$2.20		$5.34	$1.01	

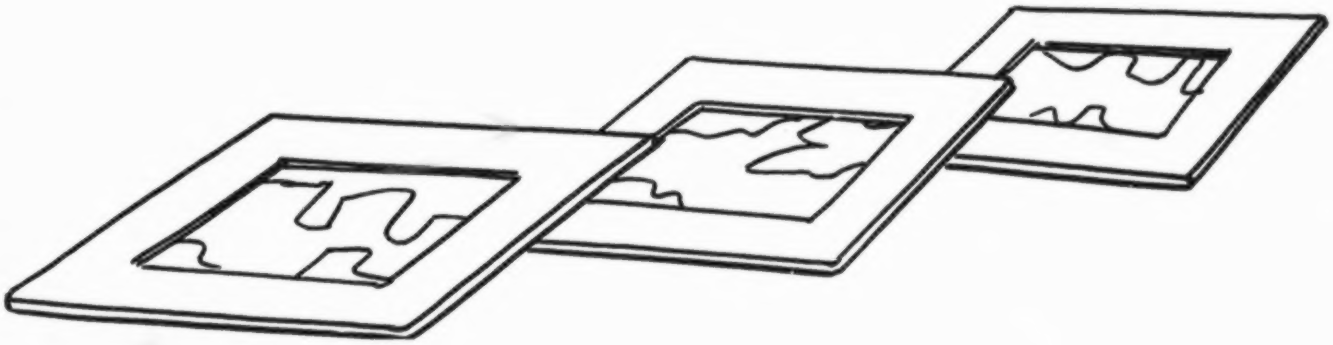
* All prices as of January 2, 1952.

Making Slides

HAROLD HAINFELD

Science Teacher and Audio-Visual Coordinator, Roosevelt School, Union City, New Jersey

(DECEMBER 1950)



After the film was processed, the students eagerly bound the negatives in 2 × 2-inch slide binders and covered them with thin glass wafers to protect the film. When projected in the darkened classroom or visual aids room, a realistic sky picture appeared on the screen. The students enjoyed the slide making. Added interest was shown in astronomy and photography. Plans now call for similar drawings and slides to be made of the solar system, phases of the moon, and eclipses of the sun and moon.

Not only did the slide-making project enable the students to "see the stars" during school hours, but their efforts contributed a valuable addition to the school's visual aids library.

Producing a visual aid suitable for a class in astronomy is a project now being undertaken by the eighth-grade students of Roosevelt School. All the equipment that is needed is a 35-mm. camera, a small tripod, one or two floodlights, and a piece of etched glass or waxed paper.

Those familiar with photography know that a black-and-white negative is the opposite of the positive print. White, when photographed, will be black on the negative, and black will be white. By photographing drawings of constellations drawn with black India ink on 11 × 14-inch white drawing paper, the negative will be black like the night sky, and the India ink drawings will be white.

The procedure for taking pictures of the star constellation drawings is as follows.

1. Mount the camera on the tripod and set the focus for the shortest distance—2½ or 3 feet on most 35-mm. cameras.
2. Set the camera for time exposure and press the shutter button. This will open the lens. Turn on the floodlights.
3. Open the rear of the camera and hold a piece of etched glass or waxed paper there. This will enable you to see the area to be photographed.
4. Place a drawing in this area on the wall or a box. This will enable you to check for proper focus. The drawing will, of course, appear up-side-down through the etched glass.
5. Lock the tripod in place. Make sure it does not move.
6. Trip the shutter to close the lens. Load the film into the camera.

All that is then necessary is to photograph the series of constellation drawings. It may be advisable to take and record a series of shots at different exposures and shutter speeds. Our experience has been that using Super-XX film with an exposure of f.8 at 1/100 sec. or f.11 at 1/50 sec. gives the best results. For illumination we use 100-watt lamps in reflectors placed 4 ft. from the drawings. Drawings in India ink appear more realistically in the negatives than drawings made with crayon, pencil, or chalk.

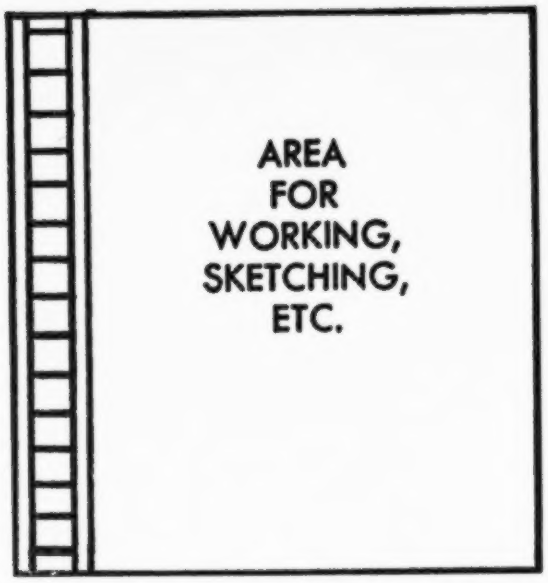


FIGURE 1. Bond paper (8½ x 11 inches) is used, as placement of group filmstrip is made on left.

Homemade Filmstrips for Science

MARC A. SHAMPO

Medical Editor, Publications Section, Mayo Clinic, Rochester, Minnesota

(MAY 1962)

Motivation of the learner and the treatment of individual differences are problems encountered in the teaching-learning environment. These problems are interdependent and the solution of one adds materially to the solution of the other. Generally, both can be handled effectively if the teacher can provide a classroom activity suitable to the maturity of each student. This activity must provide an opportunity for the student to utilize his own level of maturation and aptitude to reach his goals. Developing homemade filmstrips can improve the learning environment of any classroom and help reach these goals.

Development

The effective use of homemade filmstrips entails two distinct aspects in the teaching and learning situation. The first is the actual construction of the filmstrip and the second is the presentation of the filmstrip to the class.

The preliminary steps, actual construction and follow-up exercises in this activity, are as follows: The first step is for the teacher to allow the students to work in groups of two (or individually, although this usually is not as effective for elementary or secondary students). In selecting the members of each group, include one who can draw well and the other who can suggest "ideas." This illustrates to students the importance of capitalizing on the best abilities of each other. It also results in a better finished product, and gives each member a feeling of greater pride in his contribution.

After the selection (or assignment), each group of students should receive a sheet of ordinary bond typewriting paper. (High rag content paper generally is preferred.) The student's basic problem is to represent, in any pictorial manner, the written material and the thinking relative to the chosen topic. Words are to be discouraged in the pictorial representation. The work is divided into two phases, pictorial and oral, each of equal importance.

On the left side of the paper, a member of the group would reproduce the exact dimensions of a

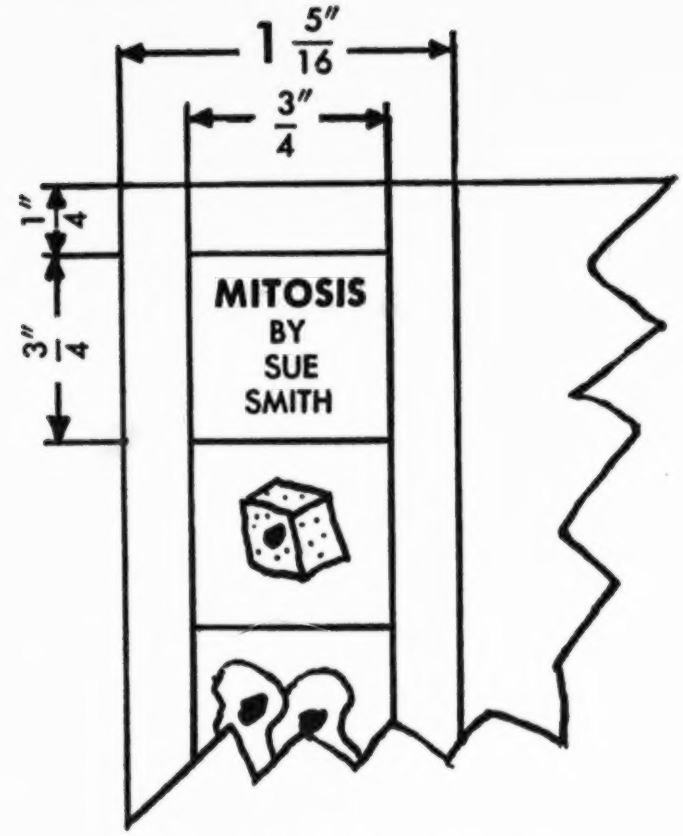


FIGURE 2. View of individual frames.

35 mm (1 5/16-inch width) commercial filmstrip. This will be a strip consisting of 14 frames, each ¾ x ¾ inches with a ¼-inch space at the top and bottom (see Figure 1). Each individual filmstrip will have a 1 5/16-inch total width (see Figure 2). The student is instructed to draw his finished product in the frames in a sequential manner, using an introduction with his name in the first frame or two to identify his contribution.

Preliminary thinking and drawing should be accomplished on the right side of the paper. It is best to draw a copy on the right side in pencil which will be transferred to the left column later at the appropriate time.

In order to supplement the main topic, each group can use reference books or exchange ideas with others. The teacher should move around the classroom with suggestions and encouragement, as needed.

Any student either gifted in drawing, or possessed of an unusual background in the general topic under consideration, should be encouraged to contribute another strip for extra credit. This opportunity helps to meet the needs of the gifted and has proved valuable in bringing in many related and interesting topics. Although each student will be working toward a goal that he has set and is within his capacity to reach, the achievement of each member of the group will differ considerably, but standards should be set.

The final grade on the filmstrip can be given for the appearance and the presentation. The appearance can be subdivided into neatness, cleverness, and originality. The oral presentation is based on the student's speaking ability and ability to communicate the material in the topic. Each student group must select that technique for presentation that is most effective, *i.e.*, lecture, question-answer, etc. Evaluation may be achieved by either the teacher or the students. Students grade each presentation for appearance and effect achieved that serves the two purposes: One, each member needs to watch and listen more intently than usual, and two, a composite grade is generally a better measure of value than any single grade. (The filmstrips are for the students.) The teacher need only to "average" grades for each student at conclusion of the work.

Referring to the mechanics of the individual filmstrip, after the initial picture is drawn in pencil, each picture in every frame should be outlined in India ink. The representation in any frame may be colored with pencil or ink to give the filmstrip a technicolor effect on the screen.

The drawing may be completed in class or at home if enough preliminary work has been done so that each group realizes the goal and understands the direction. Usually extra credit contribution will be done at home.

At a designated time, the filmstrips are to be finished and handed to the teacher. The finished product should consist of the 14 frames cut from the left of the page (see Figure 1). The next process includes the mechanics of assembling the individual contributions. This activity, consisting of assigning specific, defined tasks to be performed by members of the class, must be carefully organized by the teacher.

The first student checks each individual filmstrip for correct width. Otherwise modifications, corrections, and even rejections of individual contributions may be necessary. The next student arranges the strips into a logical sequence following the pattern of the main topic. Although each strip should stand alone in its contribution, each should add to the over-all development inductively.

After the filmstrips are organized in the proper sequence, careful gluing of each one is accomplished by two students using any regular good adhesive. The individual filmstrip now takes the form of a long roll. Next, another student, using a pair of scissors, cuts the rough edges and tapers the individual filmstrips so that movement of one individual strip to another is smooth throughout the operation.

The next two students grease the strip with lard or oil of any type to give it toughness and transparency. As the filmstrip proceeds down the assembly line, it is wiped of excess oil by carefully pressing between paper towels. Critical stages in the assembling process are measuring, tapering, and gluing, and should be checked by the teacher. Finally, the last student merely rolls the class filmstrip which emerges ready for use. It needs only to be placed in a filmstrip projector. The projector will automatically punch the sprocket holes as the strip is projected. Usually, it is best for the teacher (or project operator) to assist its movement through by gently pulling on the end of the filmstrip as he turns the sprocket knob. The oral presentation by the responsible student using any suitable methodology can now take place as the frames are projected on the screen.

Conclusion

In constructing these pupil participation filmstrips, the student has to "think" in order to change the written material into pictorial representation. There is continuity and integration of the various topics limited only by the ability of the student.

Since each student is anxious to view his individual filmstrip on the screen, student motivation is high. Short-term goals as well as longer termed goals are a part of the experience.

This pupil participation activity has many uses, limited only to the students and the teacher. For example, homemade filmstrips can be utilized for:

1. Reviewing topics in preparation for an examination.
2. "Catching up" when behind in the schedule.
3. Developing activity in the unit plan approach.
4. Evaluating specific learning outcomes.

The last suggestion offers a novel approach to testing. The use of the filmstrip for the purpose of supplementing traditional measures is quite interesting. The teacher will note two obvious differences:

1. Emotional pressure is taken off the student for a change during a "test."
2. Individual student achievement presents an interesting contrast to the more traditional approach.

Any scientific topic can be taught using homemade filmstrips. Some general framework such as a textbook or reference material generally helps insure the success of this activity, although digressions are to be encouraged for true creativity. Homemade filmstrips can aid a stimulating teacher in solving problems of motivation and individual differences in any class and at any particular grade level.

Microphotographs With the Microprojector

WALTER P. LARTZ

Chairman, Science Department, Urban Junior High School, Sheboygan, Wisconsin

(MAY 1960)

The following method has given me excellent results in making microphotographs of current subjects encountered by students in almost every phase of general science. This method is particularly useful for those who do not possess a suitable camera or do not have the equipment necessary to process the film.

Equipment needed is a microprojector, photo contact paper (F4 or F5 for sharp contrast), and developing and fixing chemicals easily obtainable at a photo supply store (Figure 1).

Set up the apparatus and procedure as follows:

1. Select the slides to be projected and mount them in the projector.
2. From left to right, lay out the developing and fixing trays. [For a 4 x 5-inch sheet of contact paper three 1000-ml beakers will work nicely in place of trays; one beaker for developer (Dektol), one for plain water for rinsing, and the third for the final fixing solution (Hypo-sodium thiosulfate).]
3. Darken the room. (Contact paper will take some latitude of light so the room is not completely dark.)

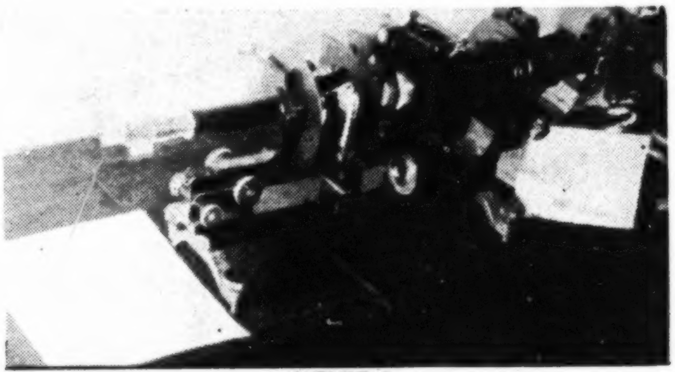


FIGURE 1.

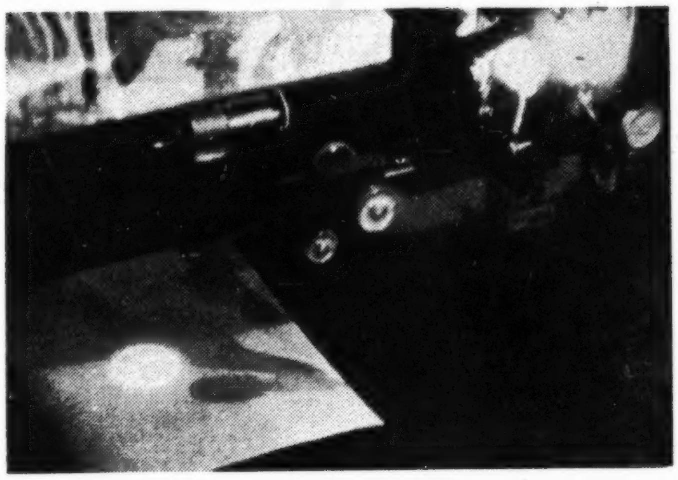


FIGURE 2.

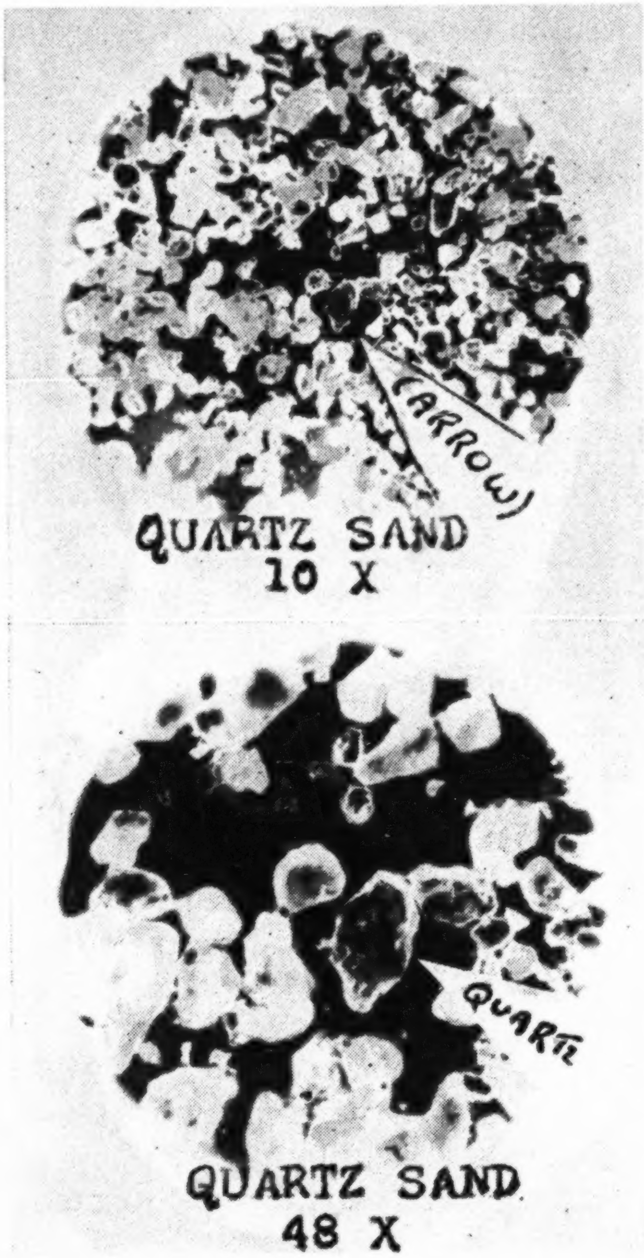


FIGURE 3.

4. Align the paper under the microprojector as shown in Figure 2 and turn on the lamp. (If the arc attachment can be taken off, a 100-watt slide projector works nicely.)

5. Expose from 6 to 17 seconds, depending upon the amount of light being projected. (Make small test strips before spoiling large sheets.) The exposure will vary with subjects.

6. Develop 1½ minutes in the developer, rinse in the water about 1 minute, and then leave in the hypo for about 10 minutes.

7. Wash the hypo out of the prints by leaving in running water for about 15 minutes and then dry by putting between blotters.

Once shown the procedure the students can easily produce prints from slides of their own making.

Small cut-out arrows from black drawing paper, laid on top of the print while being exposed, will emphasize any particular part of the print you desire. These arrows will show up as white on the completed print due to the reversal of black and white. These white arrows may then be used for easier identification of points you wish to emphasize. Printing on the white arrows may be done by typing on the finished print or by the use of India ink or a grease pencil.

Actual photos of sand grains on contact paper are shown in Figure 3. Note arrows for identification. In Figure 4 is a print made from a prepared slide of pine needles.

These prints can be used for cutouts themselves or three-dimensional models, drawings, or bulletin board work.

Enlargements can easily be made by this method also. Keep in mind that the greater the enlargement the longer must the exposure be under the projector. (Use F4 or F5 paper.) The only change is that *enlarging* instead of contact paper must be used for the enlarging paper is much more sensitive to the reduced light coming from the microprojector. (The room must be *very* dark for this particular work.) I use enlarging paper for prints of subjects larger than 50X.

An enlargement is shown of the pine needle to 168X made with the microprojector (Figure 7).

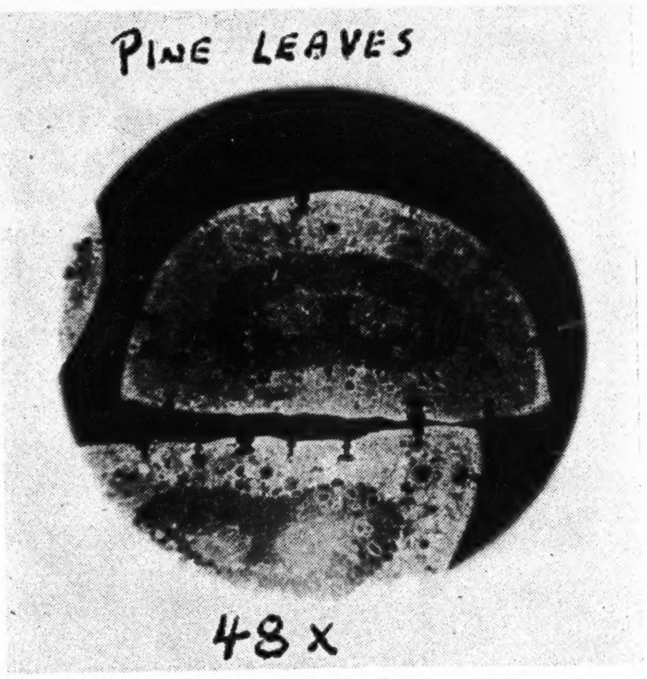


FIGURE 4.

The above suggestions will produce accurate and effective prints for classroom study and are only a few of the fascinating and instructive ideas which can be used to make a more effective teaching device.

Due to the "negative" quality of the prints, white shows up as black and vice versa, a new approach is given to the subjects themselves. I have found that these prints are especially useful for the study of sand grains for the emphasis is given to the grains which stand out against the dark background.

To change to a normal, or positive print, use the "negative" print you have just made as a negative and expose fresh contact paper by placing the two sheets together (emulsion side to emulsion side) between two glass plates for good contact and hold toward the light with "negative" print on the side toward the light. (Once again, use test strips first.)

The print in Figure 5 is a "negative" made directly by exposure under the microprojector. Figure 6 shows a "positive" print made by exposing to the print in Figure 5.

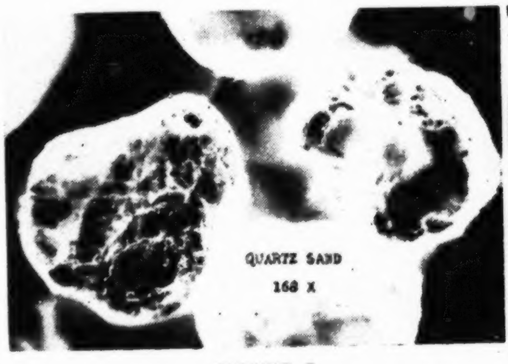


FIGURE 5.

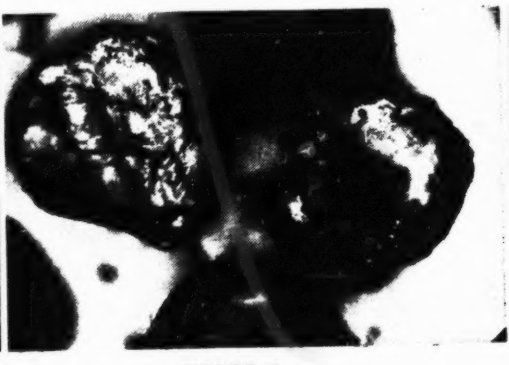


FIGURE 6.

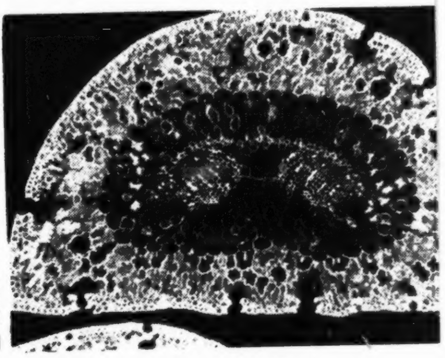


FIGURE 7.

Photography in General Science

MILAN J. KRASNICAN

Science Teacher, Chillicothe High School, Chillicothe, Ohio

(DECEMBER 1951)

The study of light presents many excellent opportunities for general science experiments involving thinking. For the purposes of this presentation "thinking" shall be defined as "the finding and testing of meaning." [1]

One such experiment was employed in a series of successive general science classes. The initial questions revolved around the broad problem of "How does the amount of light in a room affect an indoor photograph?" Some students sought to answer this query in terms such as "The more light you have, the better your picture." Thus, before we could set up an experiment, we had to be clear about our terms. What light are we talking about? Can we measure it? What are some guesses as to how we should go about setting up an experiment?

Light in an indoor classroom would be due to sunlight coming through the windows as well as the light due to the ceiling lamps. The nature of the colors within the room would also affect the amount of light reflection. If we used a flash bulb it would contribute another component of light to the total illumination within the room. Since the class had no instruments to make direct measurements on changes in illumination (e.g. in foot-candles), we decided that we could make rough qualitative estimates on the relative amounts of illumination and the consequences of these changes on our photographs.

Next, in order to have some basis for comparison, we had to have some control factors such as camera, room, film, exposure time, lens setting, shutter opening, etc. The amount of light used in exposure would be our variable. Naturally, at this level, we couldn't expect to have control over some variables, so we would have to make some assumptions or take some factors for granted. For example, clouds did not change the illumination during the taking of any photographs; the processing of the photographs was uniform, etc.

To make the experiment rather simple, the following procedure was used. Two photographs were taken of each of three classes using the same room on the same day. One photograph of each class was taken using only the sunlight and the ceiling lamps within the room. The second photograph of each class was taken immediately after the first photograph, and it contained the same elements of illumination plus that emanating from a flash bulb. Thus the addition of light due to the flash bulb could be used to determine if it had any qualitative effect on these photographs. By using three successive classes, the effect of decreasing sunlight could also be studied with the passage of time.

Figures 1a and 1b illustrate the class photographs of the 11:30 a.m. class with and without flash bulbs, respectively. Figures 2a and 2b as well as figures 3a and 3b illustrate similar results for the 1 p.m. and 2 p.m. classes, respectively. It should be noted that while the quality of these photographs is poor, a comparative analysis of them can yield rather interesting results.

In the discussion of results, copies of the photographs similar to those in figures 1, 2, and 3 were distributed among the individual classes, and a discussion of results followed.

Table 1 shows the technical data concerning the camera used in these experiments.

Table 1. Camera and Film Data

Camera Type: Kodak Tourist
Film: Kodak Verichrome
Flash bulb: SM lamp
Lens opening: f/8
Shutter time: 1/25 second

Figure 4 illustrates the qualitative relationship of the various components of total illumination at

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[1] Bode, B. H. *How We Learn.* p. 251. D. C. Heath & Co. Boston. 1940.

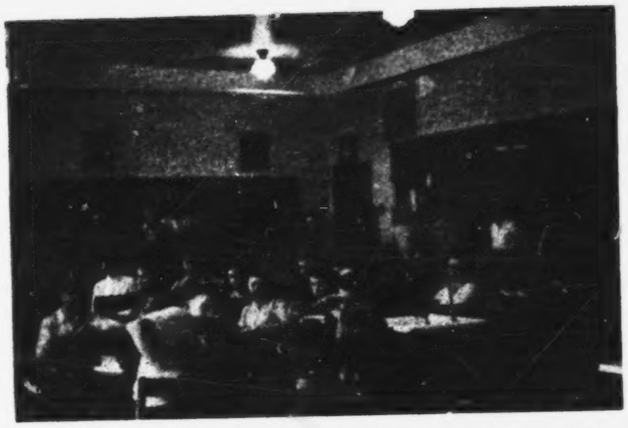


Fig. 1a. 11:30 a.m. class—photo with flash bulb.

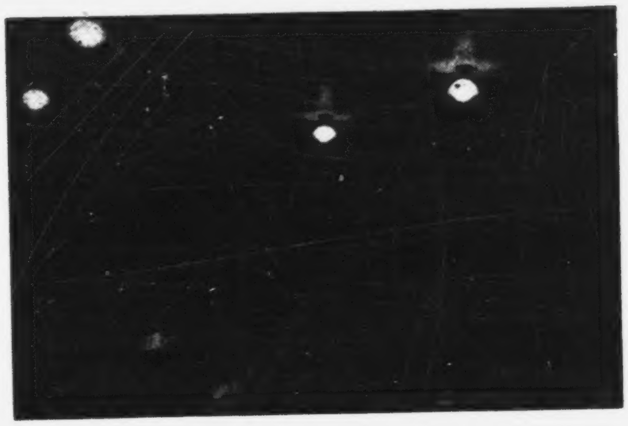


Fig. 1b. 11:30 a.m. class—without flash bulb.

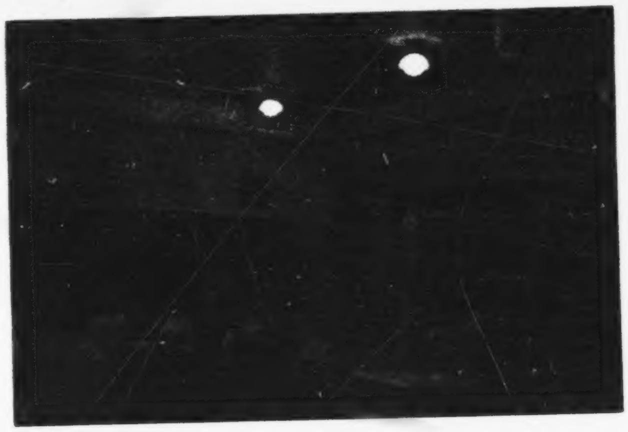


Fig. 2a. 1 p.m. class—photo with flash bulb.

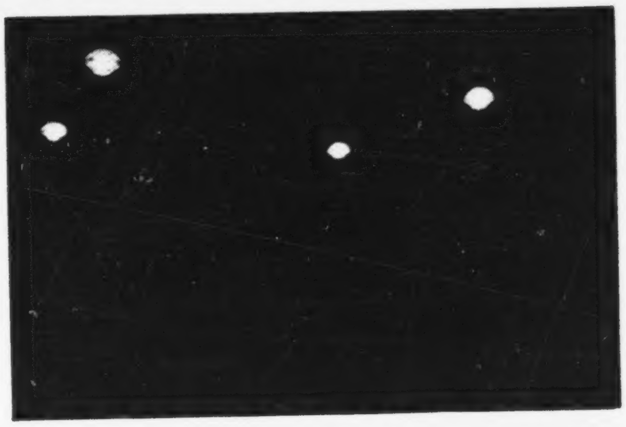


Fig. 2b. 1 p.m. class—photo without flash bulb.

Fig. 3a. 2 p.m. class—photo with flash bulb.

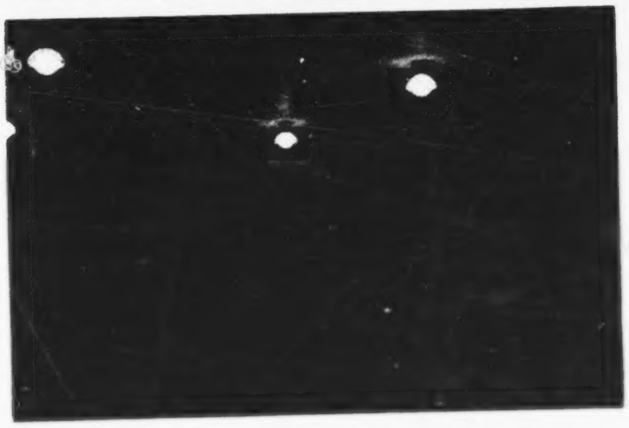


Fig. 3b. 2 p.m. class—photo without flash bulb.

various times of film exposure when using a flash bulb. The development of such a table through class discussion was found to be useful in establishing conclusions.

Note, in figure 4, that the electric lamp and flash-bulb illumination are assumed constant while light entering from the sun decreases as the afternoon proceeds. This effect is established from the photographs taken under identical conditions during various times of the day. If one eliminates the light due to the flash bulb in figure 4, one may secure figure 5.

Thus from the photographs one can make a number of restricted conclusions. For example, in the photographs taken the addition of flash-bulb illumination improved the contrast of the photographs; illumination from the sun decreased with the passage of the afternoon, etc.

In making generalizations from the experiment the class can be led to discuss limitations of the experiment and the effects of different assumptions on the conclusions. For example, one may assume that the clothing of students in each class had an appreciable effect on the amount of light reflected,

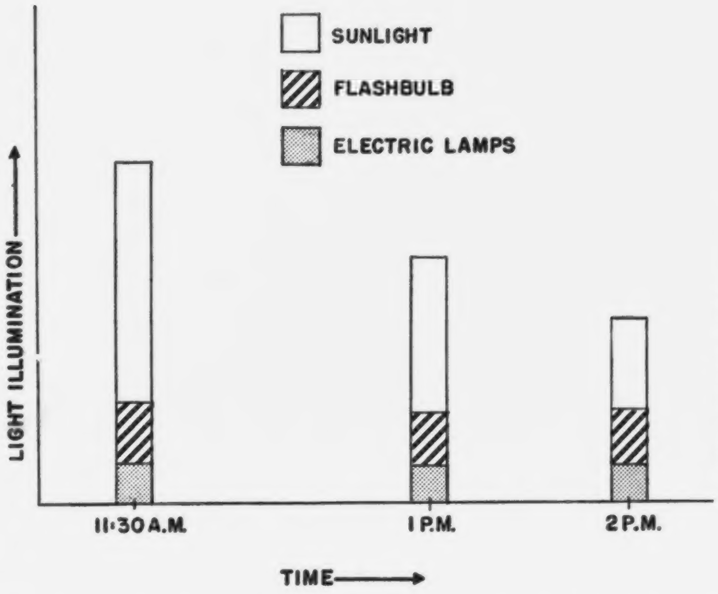


Fig. 4. Relative magnitudes of components of illumination at three exposure times with flash bulb.

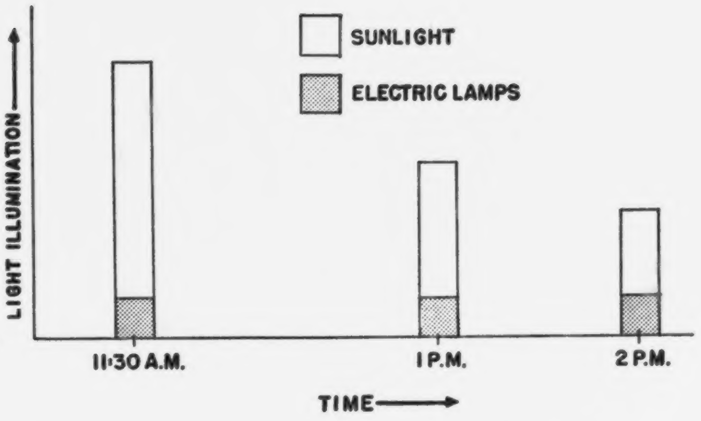


Fig. 5. Relative magnitudes of components of illumination at three exposure times without flash bulb.

and thus on the photographs. Since the experiment did not control this factor, the experiment and its conclusions would be so restricted, and this should be brought out in discussion.

Admittedly, the experiment is of a simple nature, but it can be used as a basis for future class experiments such as the following, each of which contains elements useful in developing experiences which stimulate thinking.

1. What is the effect of time exposure on photographs with outside light as a constant?
2. What is the effect of time exposure on photographs involving motion?
3. What is the photographic effect of varying the focal length of a camera lens?
4. How do different types of films affect the photograph of a given object?
5. How does the type of printing paper and the amount of developing time affect the photograph of a given object?

General Science Through Photography

HERBERT F. A. SMITH

Coordinator of Student Teaching, Southern Illinois University, Carbondale, Illinois

(NOVEMBER 1952)

Last summer at the Mankato (Minnesota) State Teachers College we conducted an experimental junior high school class in science. The approach was through photography, but the purpose of the course was not primarily to teach photography. The chief purpose was to teach children to observe more keenly, to present evidence more clearly, and to use facts more effectively in drawing conclusions from scientific study.

As the term was to last only five weeks, we plunged immediately into a study of the behavior of light in instruments such as the camera and the enlarger. During the first period together, each child of the eighteen-student group was supplied with a small convex lens and an experiment sheet with directions and questions such as the following:

> When the lens is examined, does it appear to have two flat sides, one flat and one curved side, or two curved sides? If there is a curved side, does it curve inwards or outwards?
>
> If the lens is held so that light from the sun passes through it onto a clean sheet of white paper, does the light seem to come to a point? Does it seem to spread over an area greater than that of the lens? Is there no apparent effect?

The children were encouraged to write out their own findings on the experiment sheet and to draw and write their own conclusions; most, it appeared, did. After some time was allowed for this work (there was additional material on the sheet to absorb the interest and time of the more able pupils), the group was gathered together for discussion.

The children soon concluded that, as light went through the lens, the rays were bent toward the center of the lens. It occurred to some pupils that the light rays which streamed through the windows were parallel and were not bent in passing through the glass. After some consideration of this additional evidence, it was concluded that the explanation of this apparent paradox lay in the fact that the lens had a curved surface while each window pane had two flat surfaces. From this consideration the class generalized that when light passes from one medium to another, under some conditions, the light rays are bent; it is possible to control these conditions. The teacher was then able to guide the children to a realization of the great possibilities opened after it had been determined that we can manipulate light rays by the use of variously shaped pieces of glass or plastic which we call lenses.

It would seem that an assignment to make a pin hole camera was advisable at this time, but this assignment was not made. Many of the children had made such a camera in the lower grades and many of them had heard a good deal concerning this instrument. Several boys and girls volunteered information and were able to explain the construction and operation of a pin hole camera. During the discussion, this question was raised: "If a pin hole camera works, why go to the expense of putting a lens in a camera?" One boy was quick to point out that a pin hole admits a very small amount of light and therefore permits little effective use of the camera, while a lens allows a great deal more light to enter the camera and consequently permits far more effective use of the camera.

The foregoing detailed description of the method of teaching which we used need not be continued; this example will suffice to indicate the inductive approach which was the basis of our method and which proved most successful throughout this and other courses. Children thoroughly enjoy gathering evidence, drawing and testing hypotheses, and talking over their results among themselves. The conclusions drawn by one child may be faulty and often are, but those drawn by a group of children working within the limitations of their equipment and experience, and under expert guidance, are surprisingly sound. It hardly need be pointed out that the training children receive in observation, recording, and testing is invaluable.

It might be well to speak briefly of the darkroom at our disposal. It was small and had a minimum of equipment: three trays, two ferroplates, a contact printer, a print washer, and a mediocre enlarger. The enlarger was once worth about forty dollars; a second hand one in as good condition could be bought for considerably less. Apart from the enlarger the equipment could be purchased new for about fifteen dollars.

Group Work

The whole group of pupils and nine student teachers was broken up into smaller working groups so that only a small number was in the dark room at the same time. Other activity work occupied the groups who were not in the darkroom at the time. One group worked on a class newspaper, another worked on a mural, and still others went out into the community for pictures of special interest. It was so arranged that each person had an opportunity to work in the dark room several times each week. Both the pupils and the student teachers were taught to make contact prints and each was afforded enough practice to be able to turn out an acceptable print from a fairly good negative. After experience had been gained in contact printing, the group went on to enlarging. This proved the most fascinating aspect of our efforts to many of the children and to some of the adults.

Because we had only one tank in which to develop all our negatives, this work demanded much time. As a matter of fact, many of our negatives were developed in the afternoon when attendance was purely voluntary. It must be said, though, that by thus giving the children enough time to work carefully, practically no exposed film was spoiled. It became quite evident that children of junior high school age can follow directions well enough and are also imaginative enough, to do very creditable work in photography.

A Tool of Science

Once the study of photography was launched, the children were led to a new concept: "Now that you have learned a little about photography you know a new tool of science, a new way to tell about something. How can we best use this way of telling about things during this summer?" The result of the subsequent discussion indicated that the group felt that we should study our own community and that it seemed better to go out into the community to get pictures rather than to try to photograph evidence within the school. After this general pattern had been established, the group broke up into five smaller groups who then met separately to outline practicable approaches to some problems in the community.

When the whole group had convened once more, the ideas from each of the smaller groups were written on the board and it became evident that a common thread of thought ran through the ideas presented. This was not entirely coincidental; there had been a spectacular flood in the area just two months previously and there were still many signs of destruction to be seen and photographed. Many of the questions raised dealt with flood control, soil conservation, property conservation, and so on. The group determined to study flood control and water conservation first and felt that the answers to many of their questions could be found by studying the remains of a dam which had been destroyed at the conjunction of the Blue Earth and Minnesota Rivers. As a matter of fact, the remains of the dam presented a real problem to the city. The dam had been built some years before for scenic purposes and some landowners along the river felt that it had done more harm than good. These people and some others wanted the remains removed; still others believed that it was more desirable to restore the dam.

As part of the preparation for a trip to the dam, the teacher arranged the questions raised by the children concerning the problem so that their answers would lead to other questions and ultimately to broad concepts of the effects of running water. These questions comprised a second experiment sheet, a copy of which was given to each pupil and student before the group left the school.

At the site of the dam, the children were inquisitive and active. Each child had a camera or the privilege of using one and each had the opportunity to take several pictures.

For the most part, the negatives exposed on this first trip were taken to commercial firms for development. The mistakes made by novices in printing mean only a waste of paper but mistakes made in developing negatives mean that the image imposed on the film is destroyed and, of course, the pictures are lost. After the children had obtained their developed negatives, they could hardly wait to get into the darkroom and make prints. Each was exceedingly proud when he was able to take an acceptable print home to his family and say: "This is a picture I made. It shows the debris piled up against the Sibley Park Dam." Some of the pictures conveyed the impression of the ruined dam so well that a group determined to paint a mural to express the experience more abstractly. This project in itself took up much of the time of some pupils for the rest of the session but the result was an achievement which, we felt, was worthwhile.

Project Conclusions

Much evidence concerning the effect of running water was presented by the children both through words and pictures. From this evidence, and the discussion it brought about, the boys and girls reached conclusions which were essentially as follows:

> Rivers always carry some sediment, but more sediment is carried by rivers in flood stage because the rivers eat more deeply into their banks and swiftly moving water can carry more sediment than can water moving at a moderate speed. As the flood recedes and the water moves more slowly, some of the sediment is deposited. This means that good farm land may be carried away from the farms and deposited where it is in itself destructive. Since water which is made to move more slowly by an obstruction such as a dam, deposits some of its sediment, the dam in question caused the river to raise its bed immediately upstream from the dam and this possibly contributed, to some small extent, to the flood damage. More serious, perhaps, was the fact that the superstructure of the dam (a walk built over it with steel railings on each side) trapped much of the debris and, in reality, thus built a much higher dam.

Pictures of the partially destroyed walk and of the great tree trunks and other large objects piled against the wreckage were good evidence to support the conclusions which had been reached.

The study of soil and water conservation which was based on the evidence supplied by the excursion to the dam and the surrounding area was followed by a similarly conducted study of property conservation. There were many houses and streets in the city which yet showed signs of flood damage —eroded yards, caved-in basements, and collapsed pavements. Of course, these objects lent themselves to pictorial treatment but, beyond that, the pictures of them which were made produced evidence to answer some questions and to raise still more. As a result of this study, a delegation of children visited the Municipal Building and interviewed the mayor regarding the cost of rehabilitation, the aid granted by the state and federal governments, and the part played by the Red Cross, the Salvation Army, and other such agencies.

In the five weeks available there was opportunity to use only a small fraction of the great number of ideas brought forward by the children. One unit on human conservation which would have included a study of sewage and garbage disposal, the hospitals and clinics, and the safety program of the city was hardly touched. Similarly wild life conservation, both plant and animal, offered a very attractive field for study through photography.

During the last day of school the boys and girls were shown the motion picture "Near Home" (IFB)—the story of a group of boys and girls in an English school who went out and made a study of their city of Bishop Auckland. Our pupils were able to see many parallels between the situation in our school and that of the school in England. In each case the pupil was given the opportunity to go out of the school building and find evidence for himself, to report this evidence, and to draw conclusions. There were differences, too. The English children presented their result as a bulletin board exhibit; our children presented theirs in pictures and in a newspaper. The English school is in a center where recorded history goes back 2000 years while our pioneer days are scarcely a century behind us; yet each locality tells much to him who takes the time to study what is presented.

In a discussion after the film, a student teacher asked the group if they, the pupils, preferred the way of learning which they had experienced during the summer or the more conventional methods. One boy was heard to whisper scornfully to his neighbor, "What a stupid question!"

Mock-ups in Teaching Science

MARTINUS VAN WAYNEN

Counselor and Science Teacher, Berkeley High School, Berkeley, California

(NOVEMBER 1951)

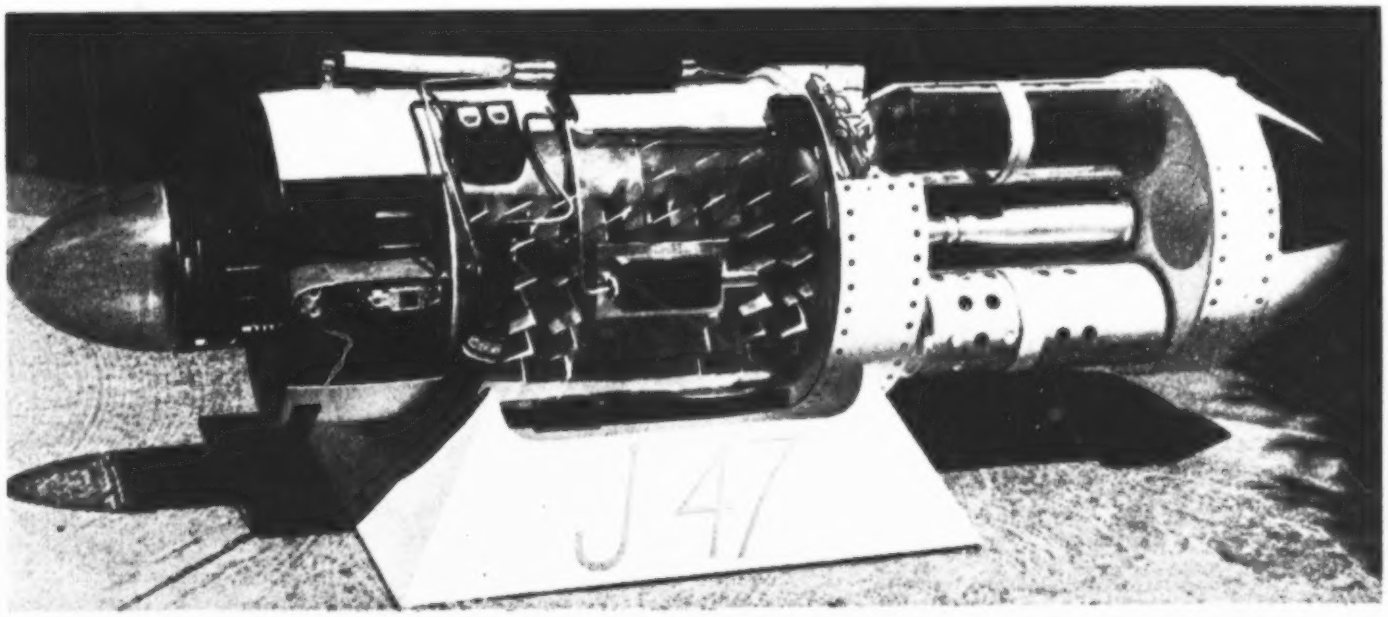
The recent emphasis placed on visual aids in education by the armed services should stimulate science teachers to re-examine what they have been doing along this line in their classes. If there is anything to the claim that the armed services can now cover months of grinding in weeks with no loss of thoroughness, we should by all means take notice.

Although the science classroom surpasses other classrooms in the use of visual aid materials, in many instances the science teacher is still handicapped by being forced to use hard-to-see toys such as pulleys one-and-a-half inches in diameter, jackscrews two inches tall, cut-away models that can be seen by only two or three pupils at a time, pieces of lodestone no bigger than a large marble, etc. Such materials are not conducive to the holding of class attention during an explanation. Pupils must see to learn. No one knows better than does a school teacher that 80 per cent or more of our knowledge enters through the eyes.

Good visual aids need not be difficult to acquire. All one needs to do is to resort to that familiar ruse —pupil projects. Suggest a list of possible topics, set up certain construction standards, and watch the visual aids pour in. Of course, teacher advice and guidance may be needed to insure a high-grade product. However, to give credit where credit is due, many of the better examples to be shown later were constructed by pupils with no teacher help at all.

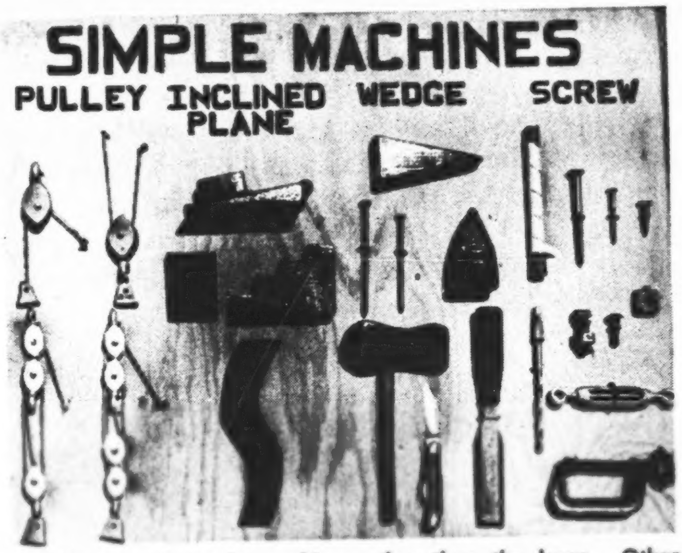
The type of visual aid to be discussed is usually referred to as a "mock-up." Mock-ups may be classified into five classes, as follows: (1) collections, (2) two-dimensional, operational cross-sections, (3) three-dimensional, operational models, (4) breakdowns, (5) three-dimensional, operational actuals.

The boards in the photographs reproduced in this article were designed to be the same size as poster board, 26 by 22 inches. This size is easily seen and lends itself well to most projects.



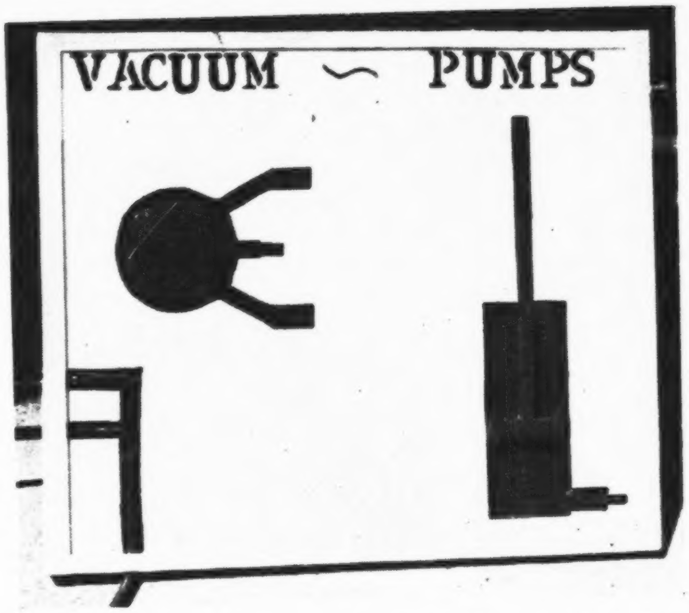
The first shown below is a collection of simple machines other than the lever. Two other excellent boards not pictured contained the three classes of levers. Other collection suggestions might feature types of gears, bearings, light bulbs, etc.

A two-dimensional, operational cross-section is represented in the illustration to the right showing three types of vacuum pumps: the rotary, the piston, and the aspirator. The rotary and the piston types can be manipulated by controls on the back of the board, while the aspirator, being the type used in the laboratory, can be connected to a water faucet and a set of Magdeburg spheres to demonstrate the actual production of a vacuum. Another good board shows the difference between the two- and four-stroke cycle gasoline engines. A light attached on each cross-section flashes on when the piston is ready for the power stroke. These cross-sections are built up of small pieces of wood and the pistons can be operated by controls on the back.



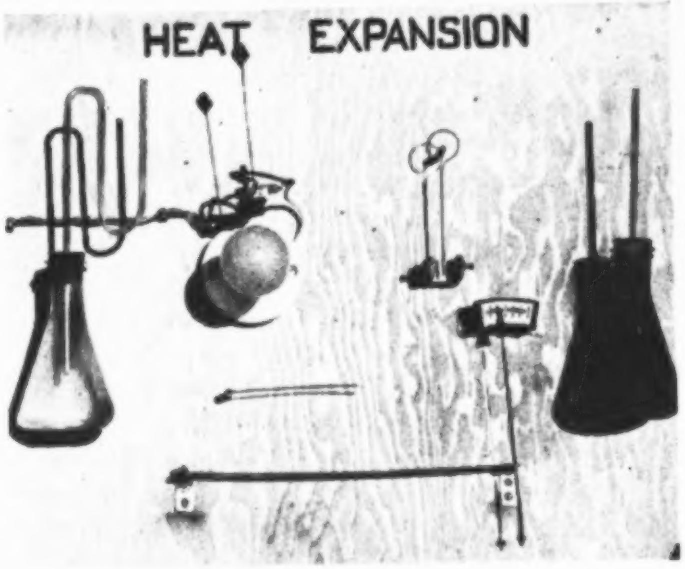
A collection of simple machines other than the lever. Other collection suggestions might feature types of gears, bearings, light bulbs, and the three classes of levers.

A three-dimensional, operational mock-up is shown in the next illustration. This is a most versatile board. When the metal strip is heated, its expansion is shown vividly by the moving pointer which it activates. Above and to the right is a flask of colored water which, when heated, expands into the tube attached. At the left is a flask which, in a similar manner, can be made to show the expansion of gases. Below the light bulb is a small compound bar and above it to the right is a sensitive thermostat element. The lamp is connected so that its heat will cause the thermostat element above it to move, tipping a mercury switch and opening the circuit. The lamp goes off and on continuously creating a great deal of interest.

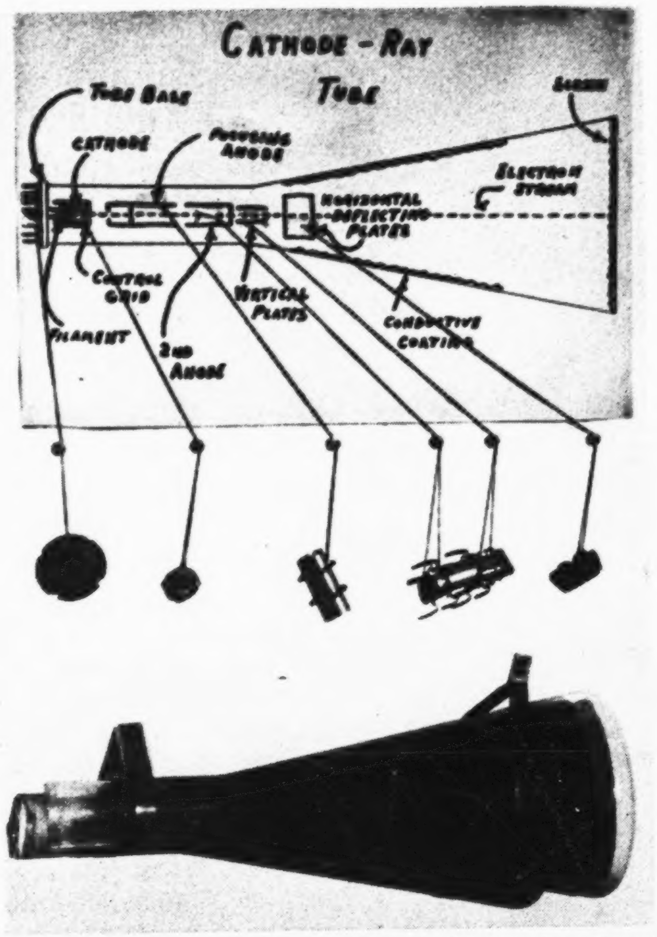


A two-dimensional, operational cross-section showing three types of vacuum pumps.

On another board (not pictured) three tubes of different diameters, with vertical tubes projecting from them, were joined together with smaller tubes and corks. These in turn can be attached to a container filled with colored liquid. When this container's height is adjusted properly, Bernoulli's principle is clearly illustrated by the decreasing heights of the liquids in the vertical tubes. This is a very effective demonstration. Still another shows a compound-machine arrangement consisting of an inclined plane, pulley system, wheel and axle, and gears. This device does a good job of teaching mechanical advantage. Another board shows electrical energy being converted to heat and heat being converted to mechanical energy. It is possible in this case to set up a problem in over-all efficiency.



Three-dimensional, operational mock-up—a most versatile board.



Clarification of the principle of the cathode-ray tube. Boards of this kind can be used to great advantage by small groups of pupils.

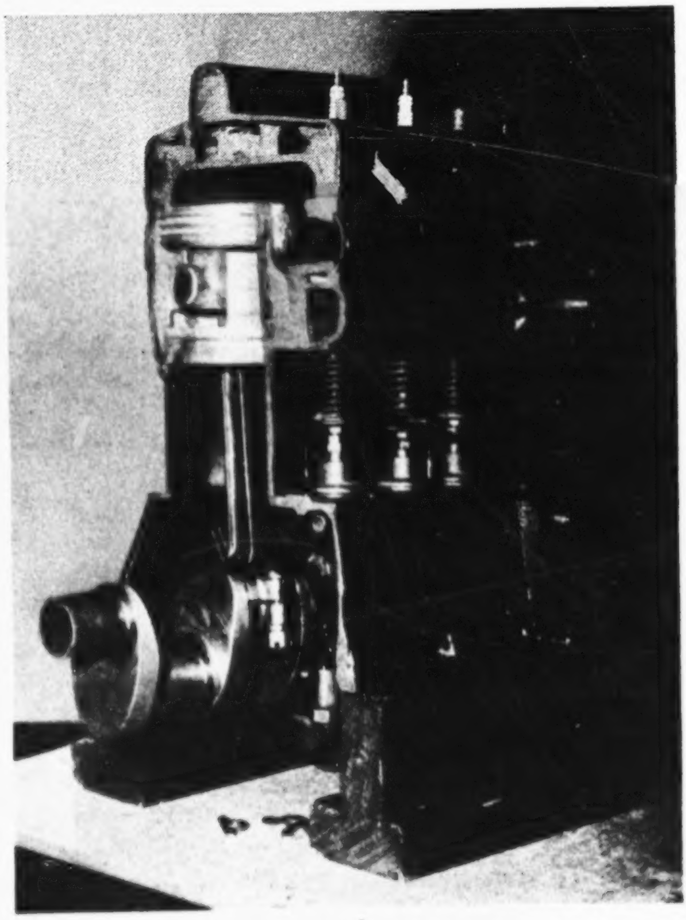
The illustration on page 244 shows an operational model of a jet engine and demonstrates what can be done with bits of plastic, cardboard, etc. Of course, this model represents a lot of work. However, the pupil who made it displayed talents which might otherwise have been discouraged and forgotten. Future pupils have acquired a high standard to pattern after, as well as an excellent visual aid in their study of the jet engine.

The breakdown shown in the picture above should suggest many others. This one clarifies the principle of the cathode-ray tube. Although the small parts on the board are rather difficult to see by a large group, boards of this kind can be used to great advantage by small groups of pupils.

Three-dimensional actuals take up a good deal of room but are perhaps the best of the visual aids. In these we have Pascal's law illustrated in the hydraulic brake, gear systems as used in the automobile differential and transmission, and the automobile engine cutaway and opened up for all to see and operate. Our list also includes two smaller boards, one having three St. Louis motors—series, shunt, and with permanent magnets—ready to operate at the flick of a switch, while the other is so arranged that a single cell can be made to operate a relay but not a sounder. By closing a switch, cutting in a six-volt source, the sounder will operate through the relay. Others, also operational, contain all that is necessary to explain fluorescent lighting, automobile ignition, and the difference between the diesel and the conventional gasoline engine. In the latter, light bulbs depict the explosions.

It was difficult to choose one of these boards to be pictured here. However, on the basis of interest shown by the class the cut-away automobile engine was chosen and is shown in the next illustration. In this model the action of the piston can be clearly seen and demonstrated. The shaft can be rotated to show the action of the valves, camshaft, gears, and driveshaft. Since the top is removeable, the second piston can also be seen to operate, as well as the upper part of the valves.

The photographs used in this article are only representatives of what can be done. Why not have your pupils try their hands at it? Do not be surprised if some of your better boards come from your weaker pupils. Remember that these boards save your time as well as that of your pupils.



Three-dimensional actual of an automobile engine. In this model the action of the piston, valves, camshaft, gears, and driveshaft can be clearly seen and demonstrated.

Science and the Flannel Board

C. LEROY HEINLEIN

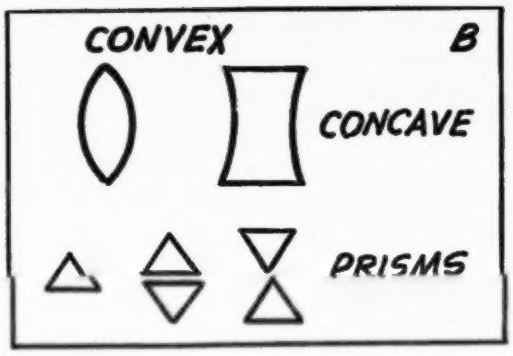
Assistant Principal, Gamble Junior High School, Cincinnati, Ohio

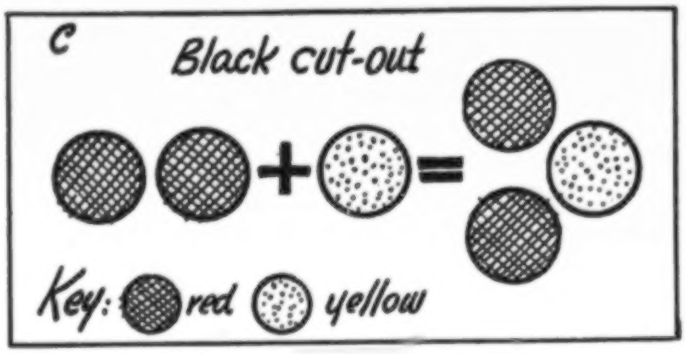
(APRIL 1955)

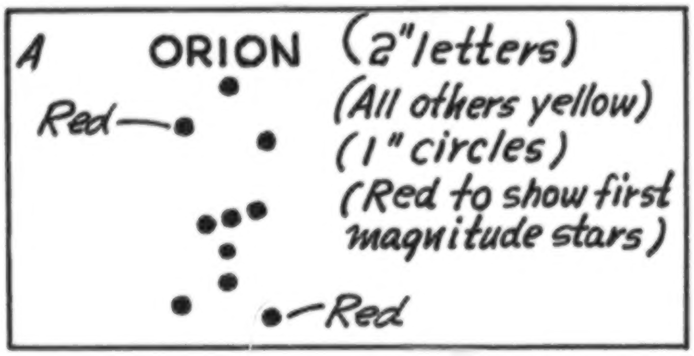
The felt board or flannel board is usually thought of and utilized as a visual teaching device for elementary schools. It has definite value with older children or adults. I have found this especially true in its use with ninth grade science classes. The objectives in its use were: to stimulate interest, to provide easy explanations of science principles and facts, to develop the creative abilities of boys and girls, to establish relationships, and to give a needed change from the traditional chalkboard demonstration.

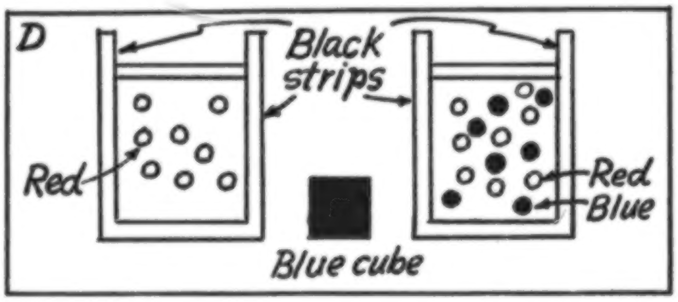
I constructed my board using a piece of beaver board, three feet by five feet, covered with inexpensive flannel (any light color), and framed with two-inch wooden strips. The entire board cost approximately four dollars. Construction paper of contrasting colors, backed with small strips of sand paper, felt, or flannel, was used to form silhouettes, forms, and outlines. Flannel or felt cutouts can be used instead of construction paper if desired. Children can, and did, make and manipulate most of the cut-outs.

The teaching of constellations in astronomy was particularly fun. One-inch circles of various colors of construction paper were used to represent individual stars, and with them one or many constellations could be shown at a time. Different colored circles could be used to point out the brightest stars in a constellation or a particular star (A). A display of constellations already prepared formed one important identification question in a written test—the children identifying the constellations displayed. Letters were cut out and used in the spelling of constellation names. In a study of light, the shapes of convex and concave lenses were cut out and manipulated (B).





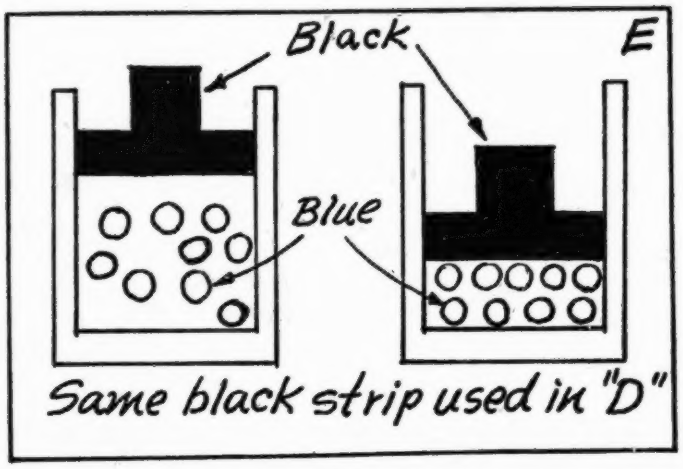


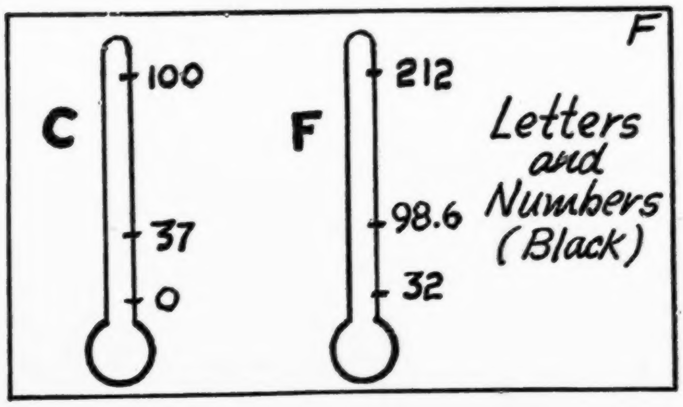


Circles of various colors (the same used in astronomy) were used to represent molecules of hydrogen and oxygen in a demonstration of the composition of water (C). This has many other applications in the study of the composition of materials.

Circles also represented molecules in a demonstration of what happens when a substance is dissolved (D). With the addition of black strips to represent the sides of a cylinder and a cut-out of a piston to fit the cylinder, the circles could again be used to represent air molecules. It was *easy* to show how air molecules are pushed closer together when you move a piston down a cylinder (E).

Thermometers cut out of red paper were used in a study of heat. A "C" and an "F" were placed at the top of each thermometer. Alongside each thermometer the children were asked to place numbers for the fixed points of each scale. Other numbers to show various temperatures (for instance, the temperature of the human body) were used. Comparison between scales was shown by the use of numbers (F).





These represent but a few of the uses my classes have made of the flannel board. It is an excellent way to illustrate a student report. There are definite applications of it in the teaching of electricity, sound, simple machines, plants, planets, and other units. Each new topic presents a new use—especially if the children are given a chance to plan, construct, and demonstrate different ideas. Before long a complete collection of forms and shapes can be accumulated and reused. Perhaps the chalkboard is easier to use, but it is not nearly the fun!

Flannel Board Experiments

CATHERINE G. COLLINS

Chemistry Teacher, Custer High School, Milwaukee, Wisconsin

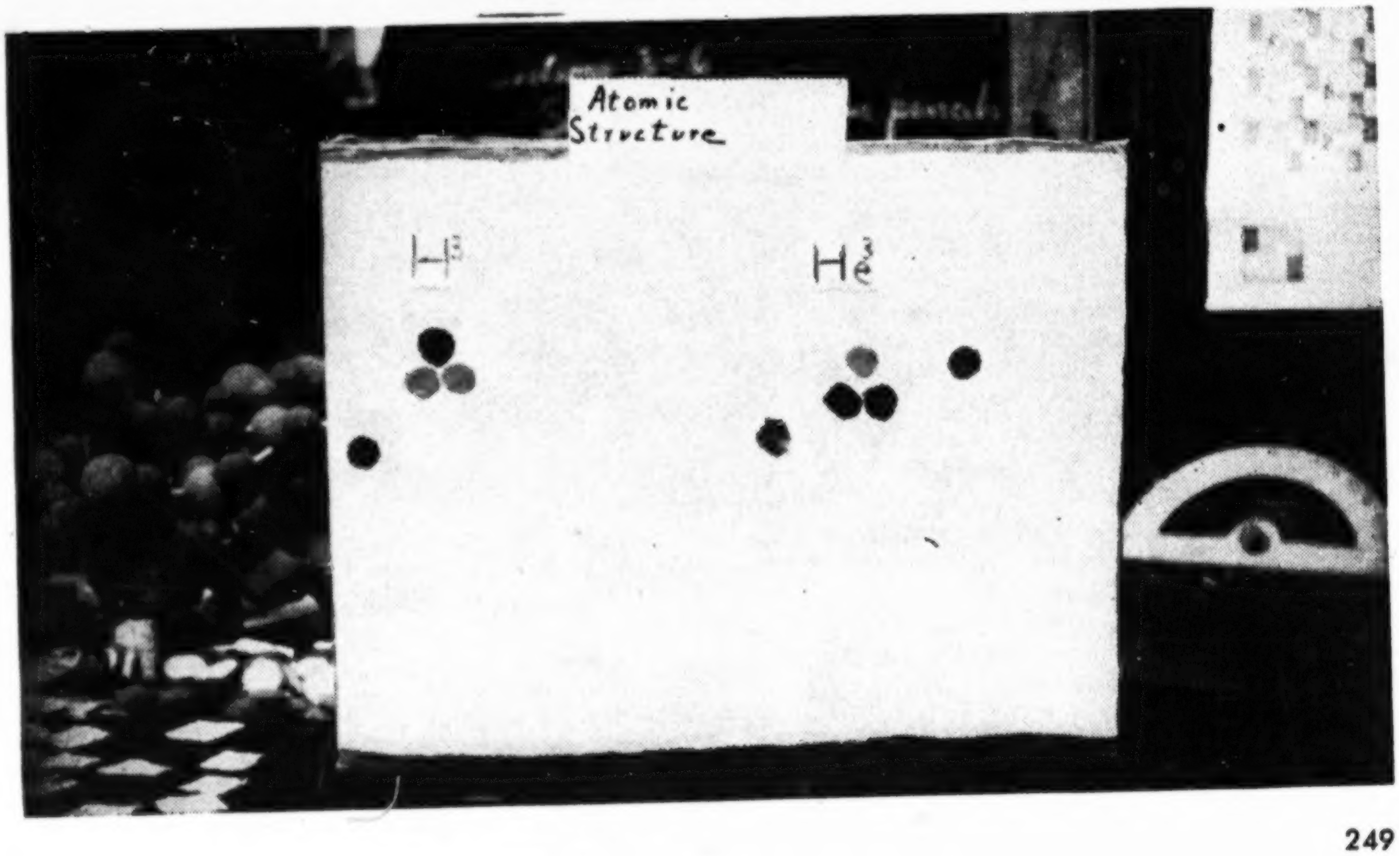
(DECEMBER 1960)

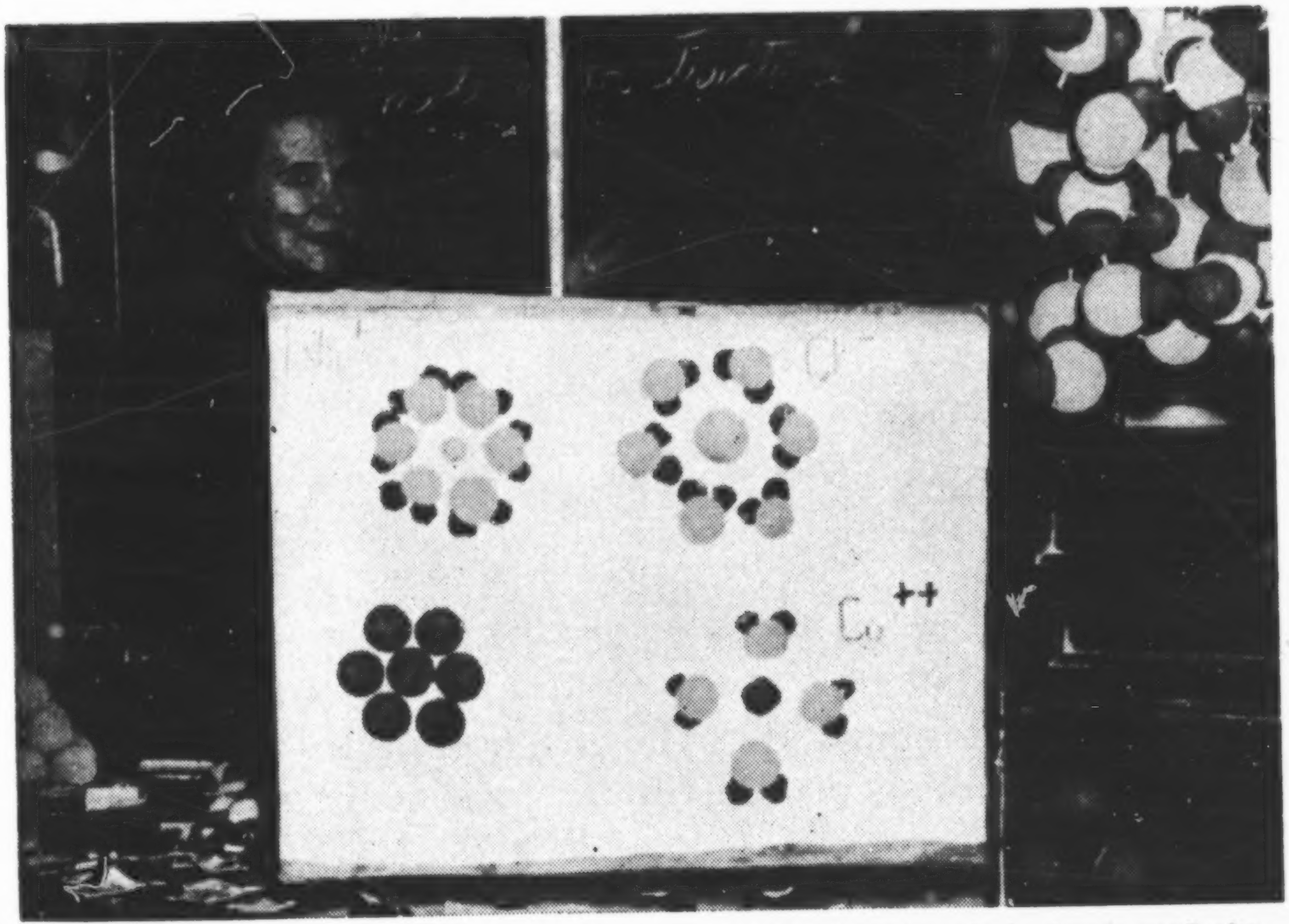
MANY OF US envy the use of the excellent demonstration equipment which appears in television science programs such as *Continental Classroom*. Dr. Harvey E. White's application of the magnetic board in explaining molecular structure recalled by experiment with a flannel board to help a slow class grasp the symbolism of chemical equations. This year the fun and satisfaction which we have had with our simply constructed flannel board and the models which we continue to create—a little better each time—have certainly been worth the personal outlay of about $2.50 for materials and the few hours necessary to complete the first constructions. After the students became interested, they were willing collaborators.

As may be seen from the photographs, the equipment is obviously homemade, but because it represents efforts of the class, they accept and value it. A cardboard box about 25 by 19 by 4 inches, once a container of newsprint, has been satisfactory as a base for the piece of light yellow outing flannel. The flannel was made to adhere with a generous amount of rubber cement. The box is light and convenient to move close to the students. Yet, it has proved to be more stable than its width would suggest. When not in use, the materials are conveniently stored inside a desk, the flannel board filed beside my desk—ready for another new inspiration.

The appliques may be made from flannel, felt, sandpaper, styrofoam, or specially prepared paper. Our nucleids and electrons are simply circles cut from colored flannel—brown for protons, blue for neutrons, and red for electrons. Although flannel with nap on both sides is preferred, the less expensive single nap will adhere under general conditions.

The relation between Tritium and Helium





The hydration of ions. The dark spheres show the closest groupings which, like water molecules, have a coordination number of six.

at the Oak Ridge Institute of Nuclear Studies. Holding up the blue side for the neutron, I began pulling out the red electron followed by the wiggly photon. The sample was then turned on the other side for the creation of the brown proton. The whole class enjoyed the "magic," and four students returned later to work out the quantitative relations.

While studying the periodic table, we might have developed a color code for our families of atoms and built up a periodic chart of our own. Many such applications come to mind as one uses the board. This feeling of creativity is one of its virtues.

Our next step was to let the symbol represent the kernel of the atom. The red electrons represented the valence electrons. As Sodium (Na) or Calcium (Ca) lost their electrons, I could flip over the symbol to show Na^+ or Ca^{++} and we could go back and forth as needed to make this concept clear and familiar. Sometimes we used strips of wool for the plus or minus signs. By next year we might make another board and copy Dr. Baxter's method of bringing up the Fluorine atom to the Sodium atom so that the two may react and form charged particles held at the characteristic distance determined by their structure.

Several covalent compounds were formed on the flannel board, but beyond hydrogen, chlorine, fluorine, water, hydrogen chloride, and methane, it seemed more natural to use the blackboard. (We had also become interested in three-dimensional models by this time.)

The board is practical and easy to pull out of the corner to illustrate a point or clarify a principle. For instance, while studying water, the structure of hydrates was questioned. To explain, we assembled the little blue oxygen atoms with the smaller red hydrogen atoms attached at their 105° angle. Four of these were oriented around the Copper (Cu^{++}) with the more negative oxygen toward the positive copper ion.

The reader can readily develop other ideas in his teaching methods. Students have suggested polka dot material for gas law representation and molecules on top of squares of felt, representing volumes, to help understand Avogadro's hypothesis.

If subliminal perception is a reality, perhaps leaving these brightly colored molecular groupings visible throughout several class periods will stimulate more experiments and be of considerable help in retaining the material.

The symbols were made on small squares of yellow flannel with heavy red pencil. To illustrate the formation of ions, the atomic symbol was lettered on one side and the symbol with ionic charge on the other. Some signs were lettered on paper and sewed to pieces of flannel. Our current "atoms" and "molecules" have been constructed in whole or part from pieces of styrofoam, by-products of three-dimensional models created from colored spheres.

In order to understand that these pieces of flannel only partially represent a portion of our present knowledge of atomic and molecular structure, we began our study of this unit with several comparisons of relative diameters and masses of nucleids and electrons. This included one game shared with the school. A sign was placed on the wall in the cafeteria. Then a pin was mounted on the sign representing the proton nucleus of the hydrogen atom. Everyone was invited to find the "electron" which would be within or near the school building. Our electron dot was about the same size as the proton, and the student committee kept moving it each time classes were changed to simulate the vibrations of the electron. It was most often "found" down in one of the far corners of the basement—probably because it is easier to picture its position in an orbit rather than as a diffuse cloud of energy vibrating even through the nucleus itself. This exercise gave the students who helped a working acquaintance with scaling and confidence in wider use of the of the metric system.

Since it was inconvenient to maintain this large representation, we agreed to work with the flannel board primarily in the classroom. The width was set as approximately 10^{-12} cm, but the empty space between particles was very small. The diameter of the particles, however, was enlarged considerably. From this point we built up the atoms, the electron shells, and orbitals by consulting the periodic chart and the lists of isotopes given in our text. Even those students who felt that atomic structure was beyond them were willing to come to the front of the class and "make" the next atom. We progressed to Neon in one period, and the class assignment was to build the next series with dots in their notebooks. This was checked with more class constructions the following day. Many students came in at noon and after school to set up larger atoms. Although the chemistry classes were the principal participants, my physics classes and the ninth-grade homeroom were also interested.

One of the extra gimmicks prepared was a large-sized blue neutron (diameter about 3 cm) sewed almost all of the way around to a brown proton. Inside was stored an electron with a reinforced wave of brown material to represent a photon. This year, one boy asked about the difference in structure of the neutron and proton when we built H^3 and He^3. I had the satisfaction of presenting what I had prepared while attending a Summer Institute for Secondary School Teachers of Mathematics and Science

Reproducible Plaster Casts

ALFRED B. BUTLER

Professor of Physics, Washington State University, Pullman, Washington

(NOVEMBER 1952)

How would you like each biology student in your class to have a large model cell to study? Perhaps you would prefer a model of the cross section of human skin, or a cross section of a corn root tip, or a model of a glaciated valley, or the thermodynamic surfaces for water or carbon dioxide. Any of these, and many others, may now be inexpensively produced with the aid of a colloidal rubber paint available at many hobby stores, or through inquiry to one of many advertisers in *Popular Mechanics* or *Popular Science*. The rubber paint is used to make flexible molds from which any number of plaster-of-Paris casts can be made.

Most teachers have seen molding sets that use a red rubber mold. These are used to produce plaster models of animals, figurines, and a large variety of knickknacks. With the rubber paint it is possible to produce such a mold of any number of objects which would be useful in the classroom.

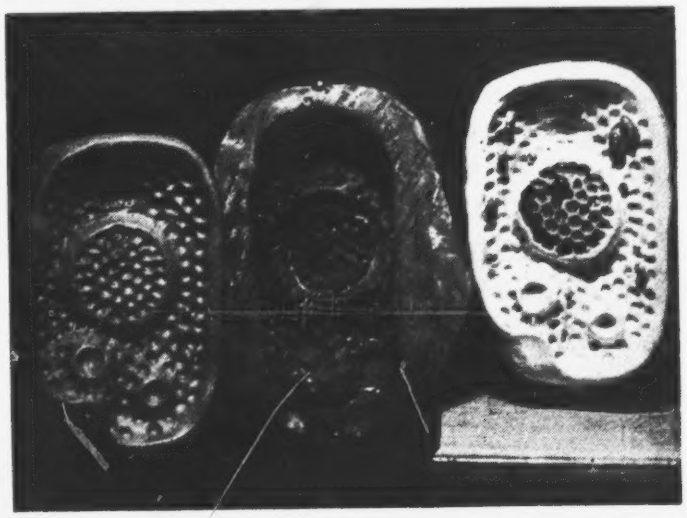
The usual procedure would be something like this. You, as a teacher, would like each student to have a model of the cross section of a living cell for study purposes. A pattern for the mold must first be made. This pattern may be made from wood or soap, but usually the ordinary variety of modeling clay is most convenient. Care taken in producing this original pattern will be repaid many times, for the rubber paint will reproduce faithfully all detail, including any careless fingerprints.

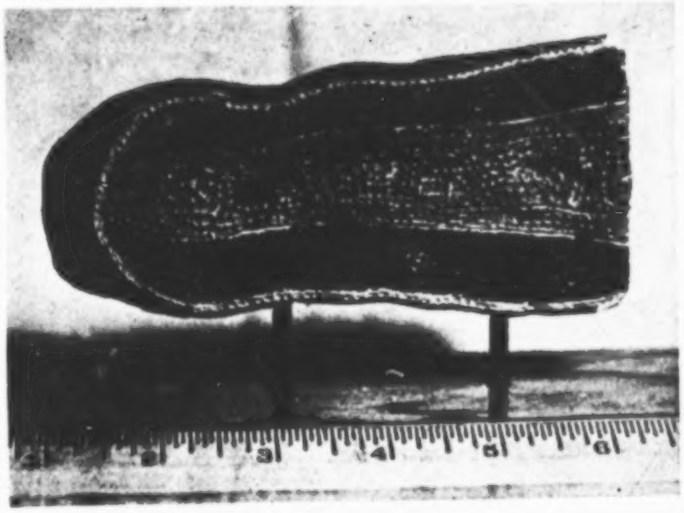
With the pattern complete, you are ready to put on the first coat of paint. Place the pattern on a piece of glass with the detailed side up. Prepare a small paint brush—one-inch size is satisfactory—by dipping it in motor oil or rubbing vaseline on it and removing any excess. This oil layer reduces the tendency for the paint to adhere to the brush fibers. Brush a light layer of rubber paint over the detailed surface, taking care not to "brush in" air bubbles. Be certain that all parts of the pattern are "wet" by the paint. The first coat may be thinned by adding a little distilled water to the paint in order to get better contact. The paint should be carried down the sides and outward on the glass surface for about an inch. This lip or rim around the mold will add strength and may be used as a support for the mold when castings are made later. The paint must be dry before a second coat can successfully be applied.

It is an excellent practice to rinse out the brush immediately, for the rubber begins to adhere within a minute or two. Careful washing in water will remove the wet paint and prevent the collection of rubber on the bristles. That which may collect can be rubbed out of the brush by pulling the bristles through your hand.

The second coat can be applied much thicker than the first coat, but care is still necessary to guard against air bubbles weakening the mold. Each coat may take from one to eight hours to dry. After the third coat has been applied, but while it is still wet and sticky, the paint should be sprayed with flock or dusted with fine sawdust. Flock is made up of very short lengths of rayon or cotton filaments which will adhere to a sticky surface, giving that surface a felt-like appearance. Phonograph turntables are usually coated with flock. This material and an inexpensive, though unnecessary, applicator are available at most paint stores or through Allied Radio Company, Chicago. The fine sawdust

This picture shows the steps in making a cell cross section—the clay pattern, the rubber mold, and the plaster cast.





Model cross-section of a root tip.

works very satisfactorily, however, and the author has used it rather than flock. This third coat strengthens the mold a great deal, but should be followed by a fourth coat, also flocked or sprinkled with sawdust, and a fifth coat to give it a final cover. Occasionally even more coats are desirable, and experience will be your guide. Usually the sides of the mold are weaker than you would expect. When this is the case, they allow the weight of the subsequent casting to bulge them out of shape. Extra attention to their thickness will result in much better molds and castings.

After the mold is complete, it can be removed from the glass plate and the clay pattern. It is best to dampen the rubber mold slightly in order that it will not tend to vulcanize itself together if two parts should happen to touch. The mold can be peeled from the pattern, turned inside out if convenient and washed with water.

Some large molds may need outside support during the casting process which follows. If this is so, the mold with the pattern inside should be set in a convenient sized cardboard box, open side up, and plaster of Paris poured around the outside of the mold. This secondary mold may well be separated into two parts by cardboard dividers in order to make removal of the mold easier. After this supporting cast has hardened, the mold can be removed and the casting started.

Plaster of Paris is mixed with water to the consistency of very thick soup and poured into the clean rubber mold (supported if necessary). This mixing and pouring of the plaster of Paris must be done without delay for it will start to harden quickly. Allow the casting to remain in the mold until quite hard. Removal may be made easier if the rubber mold is moistened and a few drops of water placed between the casting and the mold where it is first separated. Work the rubber mold from the casting and after it is washed clean in water, it is ready for storage or for reuse.

The plaster cast can now be painted with water colors, varnished or lacquered and mounted. Sometimes it is best to shellac the cast or give it an undercoat of white paint before coloring in order to seal the porous sections and make the color flow more evenly, in which case oil colors must be used. The casting may be drilled and mounted on metal rods set into a wooden base or wires may be set into the plaster at the back of the casting while it is hardening to form loops by which the cast may be supported.

Care in producing the original pattern is most important and is apt to be the most tedious portion of the job. Useful molds will accumulate, however, and in a few years an amazing variety of reproducible teaching aids will be available. Obviously more than one mold can be made from a pattern in order to expedite the subsequent casting operation.

Any scientific supply catalog will provide many ideas for possible castings. Many others will suggest themselves in addition to these, however. A model of a very young river valley and subsequent models of erosional phenomena may make general science or geography more interesting. The history of the formation of Yosemite National Park could be produced by each interested child. In physics or mathematics, any data which can be shown by a three-dimensional graph can be reproduced this way.

Such modeling is not limited to school-produced patterns, however. Fossils and other material may be safely reproduced, using exactly the same process. There is little danger of injury to the fossil if it is in relatively nonporous material, so the separation of the rubber mold will be clean. Schools could exchange plaster replicas of their best fossils.

A completed cast of a model of an enlarged cross section of human skin.

A Magnetic Board

DANIEL BRANDON
Junior High School 79, Bronx, New York

(OCTOBER 1957)

An interesting device which can be put to many uses is a magnetic board. This can be easily constructed in the shop of any junior or senior high school. The size can be made to vary with the need but I suggest a minimum of two feet by three feet.

Secure a piece of plywood about ⅜-inch thick and cover one surface with sheet iron. Metal hooks should be attached in order to hang the board either in vertical or horizontal position. A half pint of blackboard paint costing less than one dollar can usually be secured through a local dealer. Paint the metal surface of your board with this slate paint. When it is dry you can write with chalk and erase as on a blackboard.

Next comes the construction of the accessories which are used in conjunction with teaching a particular unit. The accessory pieces are cut from plywood with a coping saw. Secure small alnico magnets about one-inch long and ¼-inch wide. Gouge out enough layers of plywood to insert the magnet level and secure with "airplane" cement. Each accessory must have its own alnico magnet. Some of them may need two. The accessory, if not too big, will stick to any part of the metal surface of the board.

The uses to which I put my board include:

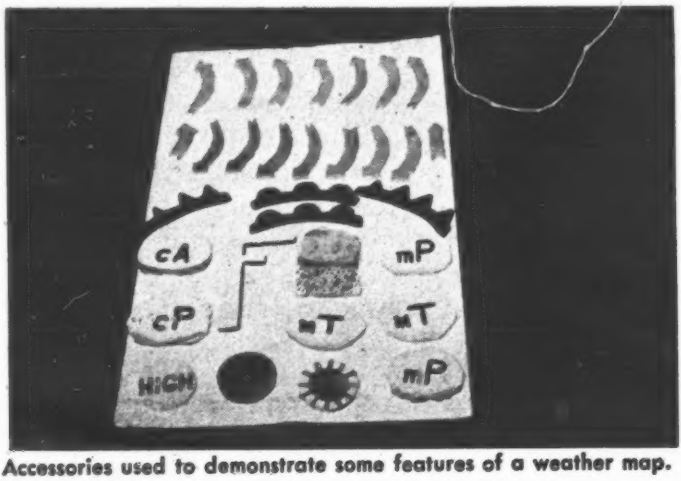
I. Weather Unit
    A. To teach air masses and their movements.
    B. To show a typical low and typical high pressure area.
    C. To demonstrate the movement of "highs" and "lows" in the United States.
    D. To indicate important features on a weather map such as fronts, rain, partly cloudy, sunshine, and location of air masses.

II. Atomic Energy
    A. To show a simple hydrogen atom of one proton with one electron spinning around it.
    B. To construct other nuclei of other elements such as helium, lithium, beryllium, carbon, nitrogen, boron, and oxygen.
        (The neutrons may be painted green to indicate no charge and protons, red, to indicate positive charge.)

The degree to which this device can serve a teacher is limited only by imagination and ingenuity.

WEATHER MAP
HIGH
LOW

Accessory pieces used in conjunction with the weather unit.



Accessories used to demonstrate some features of a weather map.

The Pegboard in Sci-Math Instruction

SISTER MARY EVELYN, O.P.

Chairman, Science Department, Saint Paul High School, Santa Fe Springs, California

(FEBRUARY 1959)

FOR SEVERAL YEARS, the pegboard has been used for attractive displays in libraries and department stores. Its function as a science teaching tool is considered here.

Diagrams and pictures help convey ideas, but they do not equal the "real thing" or a working "3-D" model. Here, the pegboard steps in. The one-inch perforations make possible almost any arrangement of equipment, secured by string, heavy thread, or fine wire. Specific suggestions would include a display of apparatus for an identification quiz or a model to illustrate some process, as water purification. Such displays can be mounted and left in the classroom as long as needed, moved from room to room, or used in display cases. The entire display occupies only slightly more space than the board itself. Hardware stores and library supply companies carry all types of "gimmicks" for pegboard displays. However, the purpose of this report is to describe uses of the pegboard other than conventional display. Several teaching tools employing the pegboard were developed. Each may be used in lecture-demonstration by the teacher and in learning-through-participation by the student.

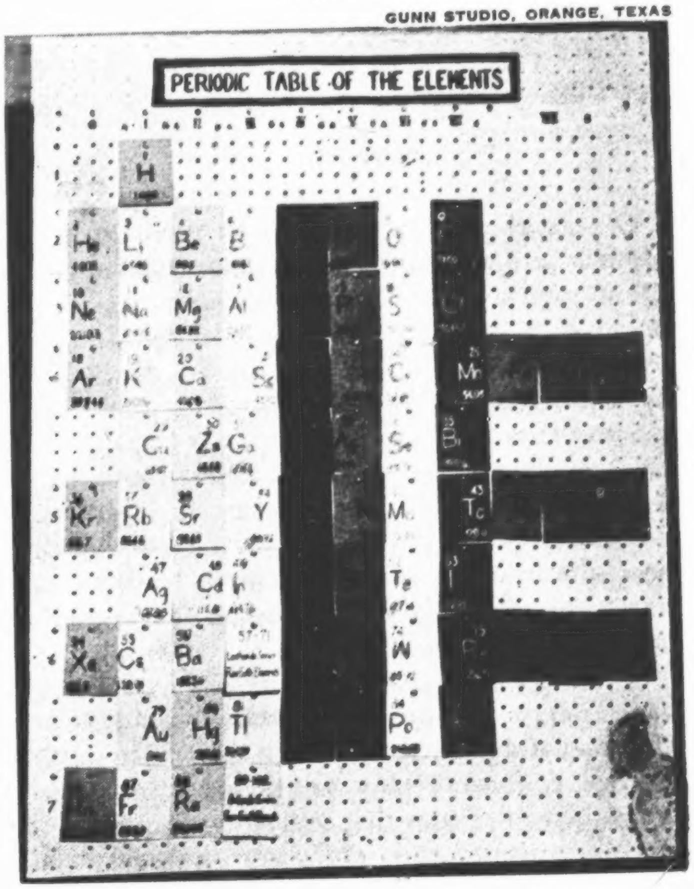
Periodic Table

The first display (Figure 1) aims to make the periodic table more meaningful to chemistry students. The idea of a variable periodic table was not original. It was taken from "A Variable Periodic Table" by Roderick Scheer, Waldoberscherle, West Germany in *Journal of Chemical Education*, November, 1955, (p. 590-591). The plan outlined in the article was modified considerably.

Using cards of different colors makes each "family" stand out from the others. Having a separate card for each element makes possible the conventional arrangement usually seen on standard laboratory charts and the long form used in many recent texts. In the "short" form, by stacking the cards and arranging them book-fashion on one fastener, the lanthanide and actinide series can be placed in their proper positions on the chart, rather than at the foot of the chart. A particular group of elements (metals, non-metals, etc.) may be spotlighted by placing only these cards on the board. The cards are attached to the board with ordinary brass paper fasteners.

Figure 1

GUNN STUDIO, ORANGE, TEXAS



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[1] Sister Mary is now at Newman Hall, University of Texas, Austin, Texas, attending the NSF Institute program.

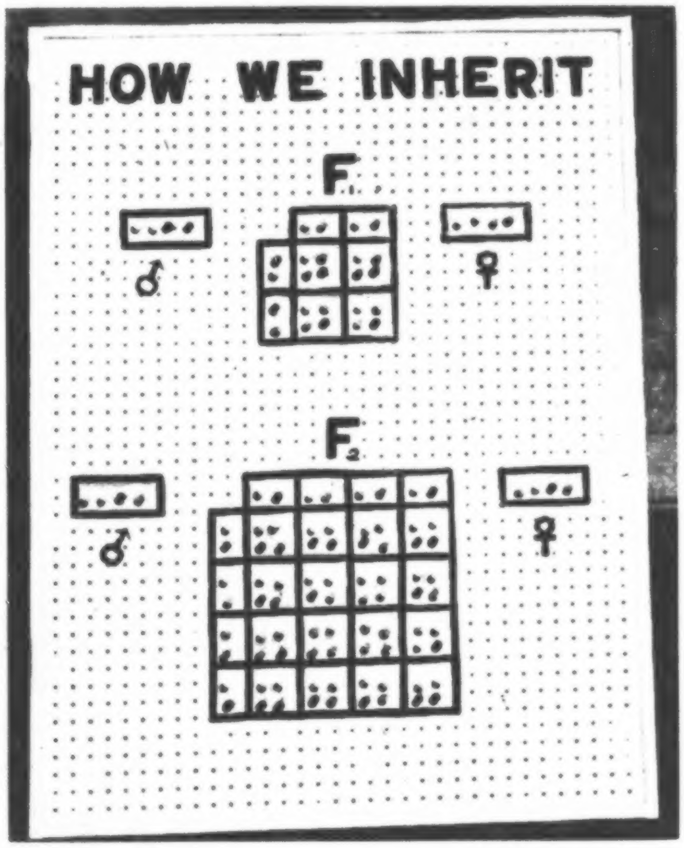
For the cards, ordinary construction paper was cut into 3" x 4" pieces. Color combinations are optional, but it might be suggested that black be used for group IV (carbon, etc.), light yellow for group VI (sulfur, etc.), gray for the inert gases. Brick red for group V puts phosphorus on a red card. Hydrogen's unique characteristics compared with those of the other members of group I are emphasized by using a different shade of the color employed for the other elements in this group. The symbol, the atomic number, and the atomic weight of the element represented were printed on each card, the "A" groups being printed to the left side of the card and the "B" subgroups to the right. Use of a stencil lettering guide is strongly recommended. The following captions are printed on strips; for the conventional form: A^{I}B, A^{II}B, etc., for the heads of the vertical columns, and 0, 1, 2, etc., to designate the periods running horizontally; for the long form: light metals, heavy metals, non-metals, and others.

Other captions may be made for spotlighting particular groups, such as "calcium family," or "halogens."

Heredity

To self-conscious teen-agers, heredity is an intriguing study. To illustrate Mendel's experiments, and to chart the first and second filial generations, sections were drawn on the back side of the pegboard (Figure 2). The letters and symbols were cut from black construction paper and attached with poster wax. Golf tees were used to represent the genes. Two shades of green were used to represent one pair of dominant and recessive characteristics and white and yellow to represent a second pair. The latter colors were chosen as a pair because tees were purchased so colored. The pegs were painted by being dipped in the paint. Wooden tees were used because their solid heads contrasted with the hollow plastic pegs. Demco Library Supply Co., Madison, Wisconsin, sells a peg with a flat head similar to that of a thumb tack. These would be more satisfactory because of the uniform size of the peg portion. Kindergarten pegs, which come in assorted colors, might also be used. However, these have no "heads" and would not be as easily seen from a distance. Because of immediate availability, golf tees were used for our purpose.

To construct the illustrated display, 30 pegs of each color are needed—with a few extras to compensate loss. Any number of pairs may be provided. Any combination of genes in each "parent" is possible by merely changing the color of the pegs. This provides opportunity for endless predictions of possible offspring. The form drawn provides for two characteristics to be predicted simultaneously. Of course, it may be used to predict the outcome of a single characteristic also. The pupils are encouraged to vary these experiments and to chart the results.



GUNN STUDIO, ORANGE, TEXAS

Figure 2

Choosing any "parents" produced by the F_2 generation, one may chart F_3, and so on. The "parents" are placed in their proper "boxes," then, their genes, in the transmittable combinations, are arranged in the spaces on the top and left sides of the chart. These combinations guide the arranging of genes in each "box." Pegs not in use can be aligned in the spaces below and to the sides of the chart proper.

Trigonometry

If the pegboard area is divided into four guadrants, it can be used to represent "giant-sized" graph paper for the plotting of points in algebra and trigonometry. Each hole may represent one unit on the graph. Pegs are inserted at the proper points. Fastening lengths of various colors of yarn to the center of the board makes possible vivid demonstration of the positions of the sides of obtuse angles and the determination of their functions as well as of the functions of the quadrantal angles.

For this demonstration two 36″ lengths of each color of yarn are needed. Pegs are placed at the proper points and the yarn drawn from the origin to these points. If the piece of yarn forming the radius, or rotating leg of the angle, is passed over a peg at the proper point, the remaining length being dropped as a perpendicular to the proper axis, passed around another peg, and directed along the axis to the origin, the students can quickly visualize the right triangle used to calculate the functions of the particular obtuse angle (Figure 3). Angles greater than 360° can also be illustrated.

The technique just described was used very successfully with a class that found difficulty adapting itself to thinking trigonometrically. Several members had failed to grasp the significance of plotting points on graph paper in their previous algebra classes and were infected with a real "graph-phobia." Using the pegboard to review and reteach the principles involved before applying the technique to obtuse angles did much toward tearing down the mental block and toward bolstering the students' confidence in attacking a new task.

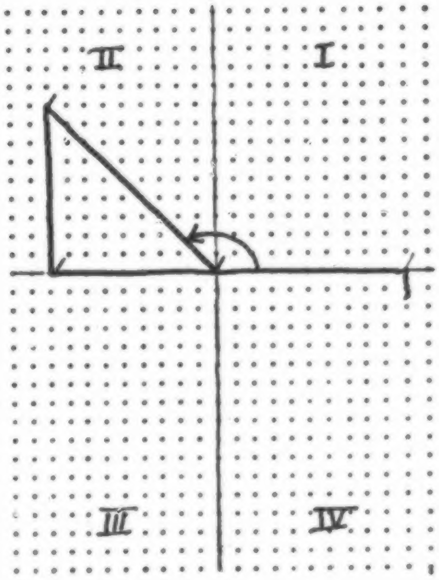


Figure 3

Pegboards and accessories may be purchased from most school or library supply houses. Or, a teacher with limited funds and less limited imagination might join the "do-it-yourself" trend. The pegboard used in the described demonstrations was purchased from a lumber company for $1.92 (3′ x 4′ masonite ⅛″ pegboard). Wood strips for the frame cost an additional 86 cents. The board was painted with left-over wall paint. This made the surface washable and glare-free.

The described demonstrations are just a few suggestions. The ingenuity of the individual teachers is the only limiting factor to the teaching tools and techniques to be found in the pegboard.